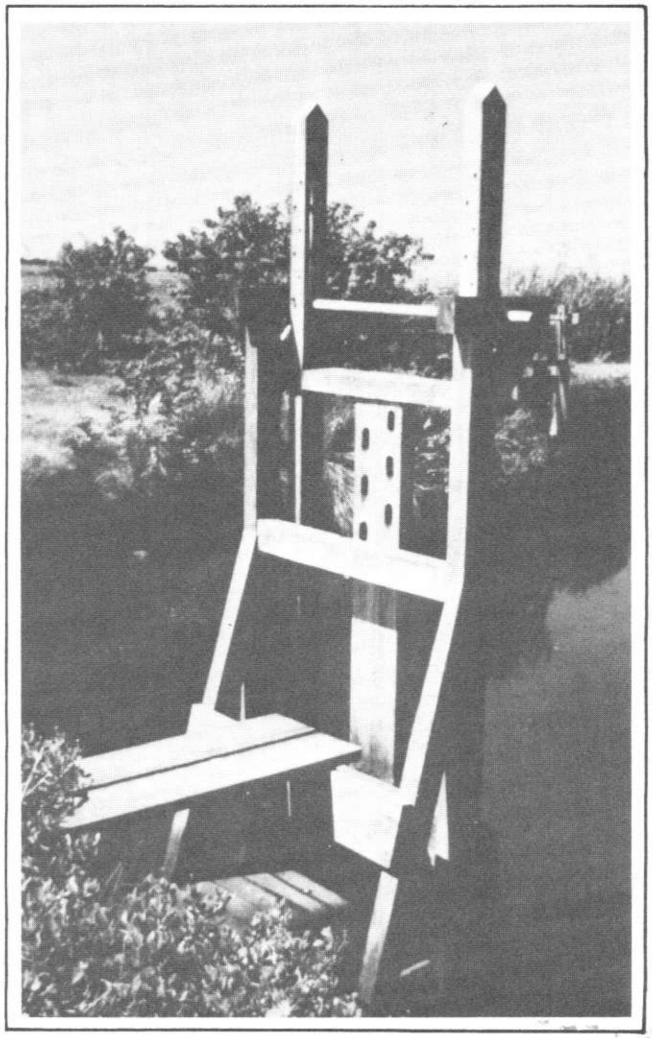
South Carolina
Sea Grant Consortium

# SOUTH CAROLINA COASTAL WETLAND IMPOUNDMENTS:

## Management Implications

WORKSHOP PROCEEDINGS

Sponsored By:
SC Sea Grant Consortium
Clemson/Sea Grant Marine Extension Program
SC Wildlife and Marine Resources Department
Kinloch Plantation



Technical Report #SC-SG-TR-87-1

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## Management Implications

WORKSHOP PROCEEDINGS

Wampee Conference Center
Pinopolis, South Carolina
March 1987

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South Carolina Sea Grant Consortium
Clemson/Sea Grant Marine Extension Program
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and
Kinloch Plantation

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This workshop is a result of research sponsored
by NOAA, National Sea Grant Program Office,
Department of Commerce under Grant Nos. NA81AA-D-00093,
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# WELCOME AND INTRODUCTION TO THE IMPOUNDMENT MANAGEMENT WORKSHOP

M. Richard DeVoe
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Charleston, SC

On behalf of the South Carolina Sea Grant Consortium, the South Carolina Wildlife and Marine Resources Department, Clemson/Sea Grant Marine Extension Program, and Kinloch Plantation, I want to welcome you to the Wampee Conference Center for our workshop entitled "Coastal Wetland Impoundment: Management Strategies." I am Rick DeVoe, Associate Director with the Consortium, and I will be moderating this afternoon´s workshop.

The focus of today´s workshop is on some of the issues related to coastal wetland impoundments and their management. Our purpose is two-fold: (1) to familiarize you with the results of our recently completed Coastal Wetland Impoundment Project (CWIP) as they relate to impoundment management, and (2) to present specific suggestions for management innovations which may address many of the concerns raised by different groups and highlighted by our research. Let me provide you with some background.

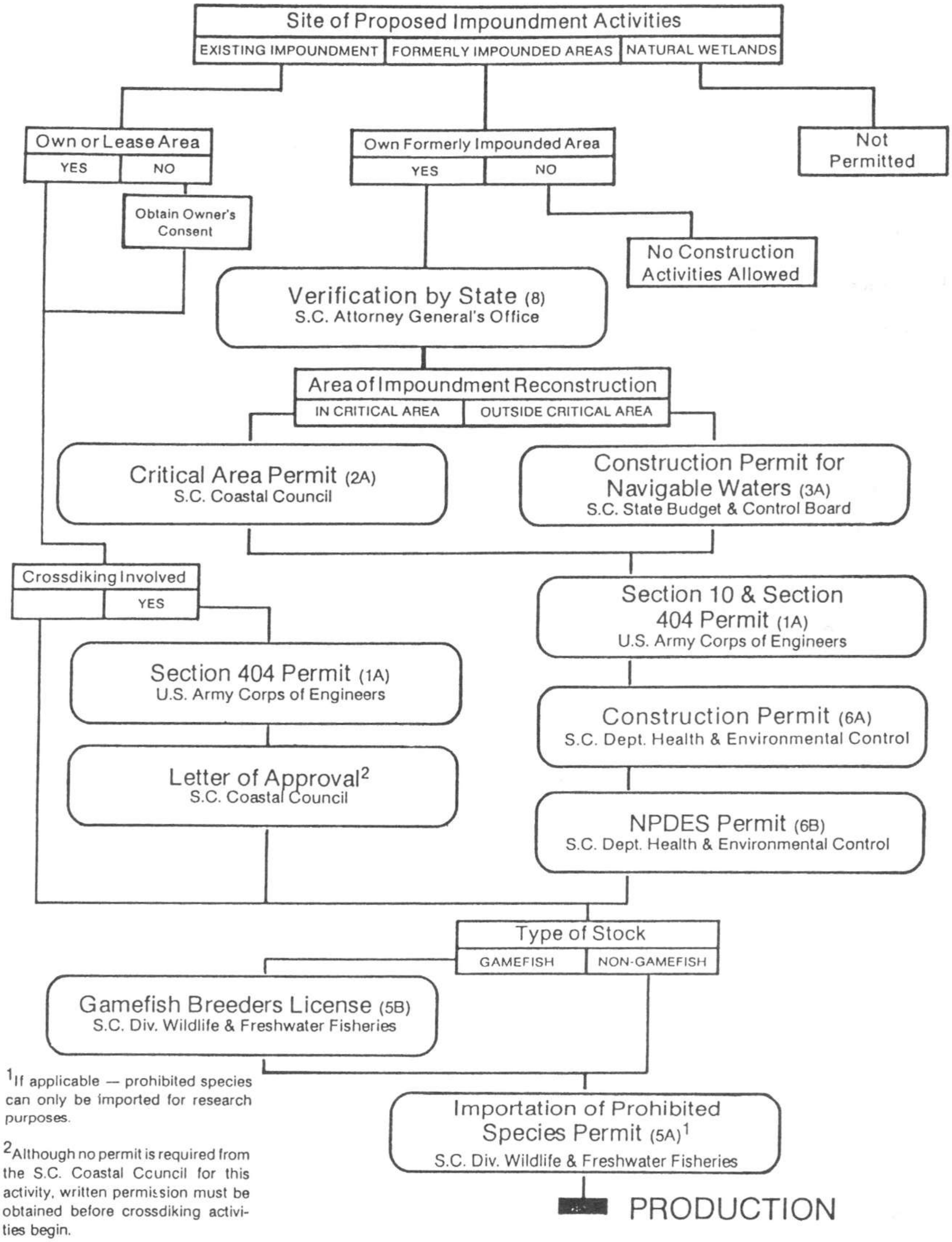
The Consortium initiated the CWIP in 1982 to look at three aspects of impoundments: (1) the "science": decision-making on applications for impoundment-related activities is occuring with very limited scientific information; (2) "policy": the number of agencies involved, and their differing policies with respect to impoundment activities causes confusion; and (3) "management:" there is minimal documented information available on effective impoundment management strategies. Let me expand on each of these.

First, as Doug Baughman will describe in the next paper, the Consortium structured the CWIP as an intensive ecological characterization of a set of impoundments and compared results with those from similar studies on an adjacent marsh. Prior to the CWIP, no such comparisons existed. With the CWIP, we were able to identify several ecological characteristics and trends which we feel shed some light on some of the scientific issues regarding impoundments (which Doug Baughman will discuss). With this additional information, we feel that decision-makers have a better idea of what the trade-offs will be with any given decision they make.

Public policy issues have been the subject of intense debate with respect to impoundment systems. Questions of ownership rights (public versus private), regulatory policies, conservation versus development, and others have surfaced. I think most of you are familar with the situation regarding the regulatory process in South Carolina; some 13 federal, state, and local agencies can be involved in a permitting process that proceeds more or less according to the flow chart in Figure 1 (DeVoe and Whetstone, 1987). The information derived from the CWIP will not, of course, have much impact on the number of agencies involved in the process, or on the process itself, but it does shed some light on the validity of a number of issues that have

FIGURE 1

# Permit Structure: Impoundments




[1] If applicable — prohibited species can only be imported for research purposes.

[2] Although no permit is required from the S.C. Coastal Council for this activity, written permission must be obtained before crossdiking activities begin.

emerged over the last five to ten years.

Third, results of the CWIP led us to believe that the only practical way to address concerns with impoundments was through the examination and testing of existing and modified management strategies. We know from the surveys conducted by Dr. Mark Tompkins of the University of South Carolina as part of the CWIP that the <u>intensity</u> of current impoundment management practices varies widely (Figure 2) (Tompkins, 1986). This information suggests that the majority of managers actively manipulating water levels and flow in their impoundments use more intensive methods (e.g. multiple draw down-reflood events with cultivation of the beds). Additionally, the more intensive management schemes tend to be used more by "public" managers, as illustrated in Figure 3 (Tompkins, 1986).

This leads me to the following points regarding the management of impoundment systems in South Carolina, which are based on information provided by public and private managers. First, it has been estimated that approximately 50% of our <u>existing</u> impoundments are <u>not</u> managed to their full potential, thus effectively limiting their productivity. Secondly, the more intensive the management, the more productive the system. And, based on the information provided through the CWIP, which identified potential impacts of managed impoundments on adjacent systems, the possibility exists to address and minimize these effects and maximize productivity through the testing and transfer of innovative management strategies to impoundment managers.

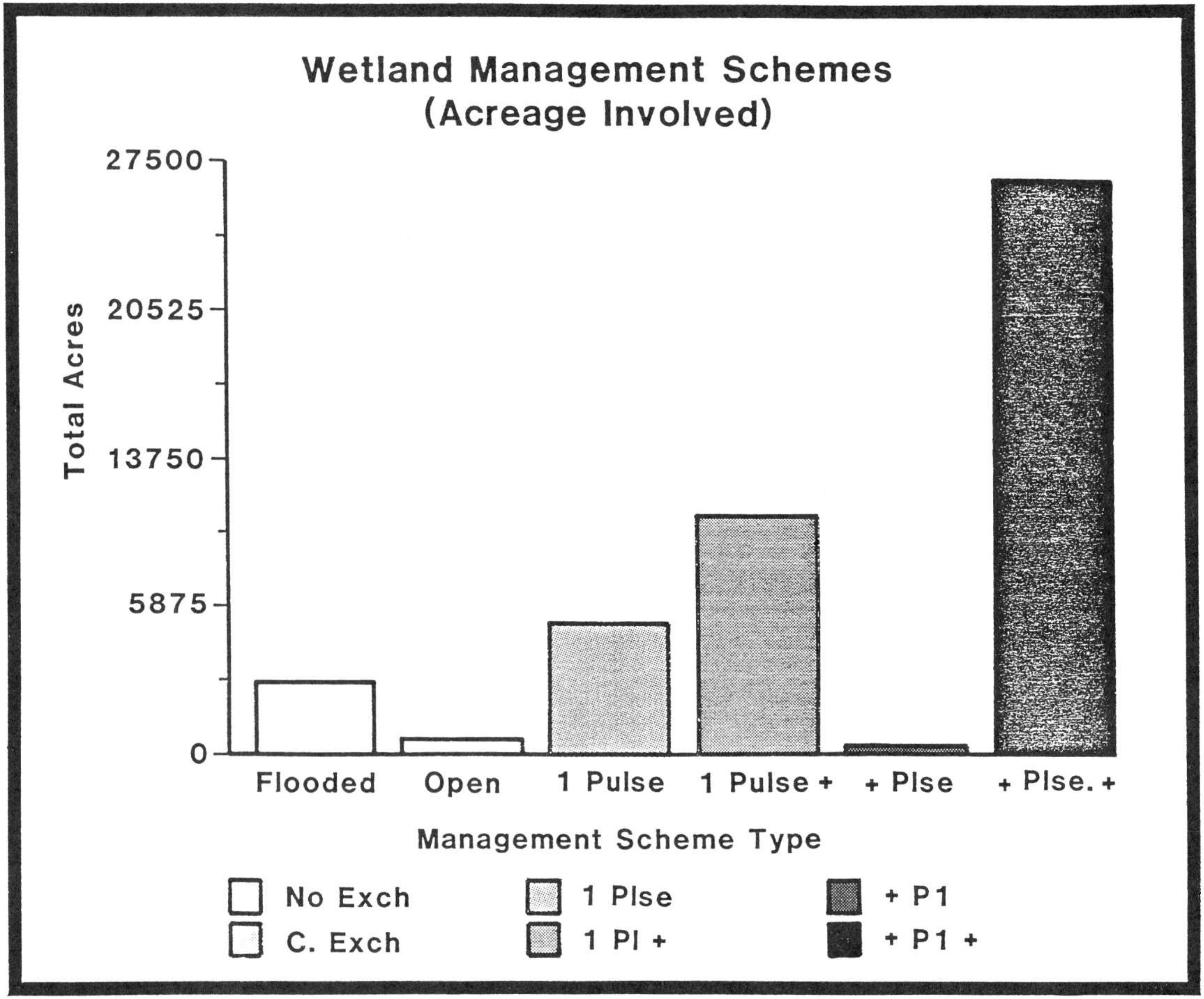



Figure 2. Acreage of Impoundment sites categorized by management regimes. Scheme types: No exchange; continuous exchange; one pulse drawdown and flood; one pulse drawdown and flood with manipulation of the bed; multiple pulse drawdown and flood; and multiple pulse drawdown and flood with manipulation of the bed.

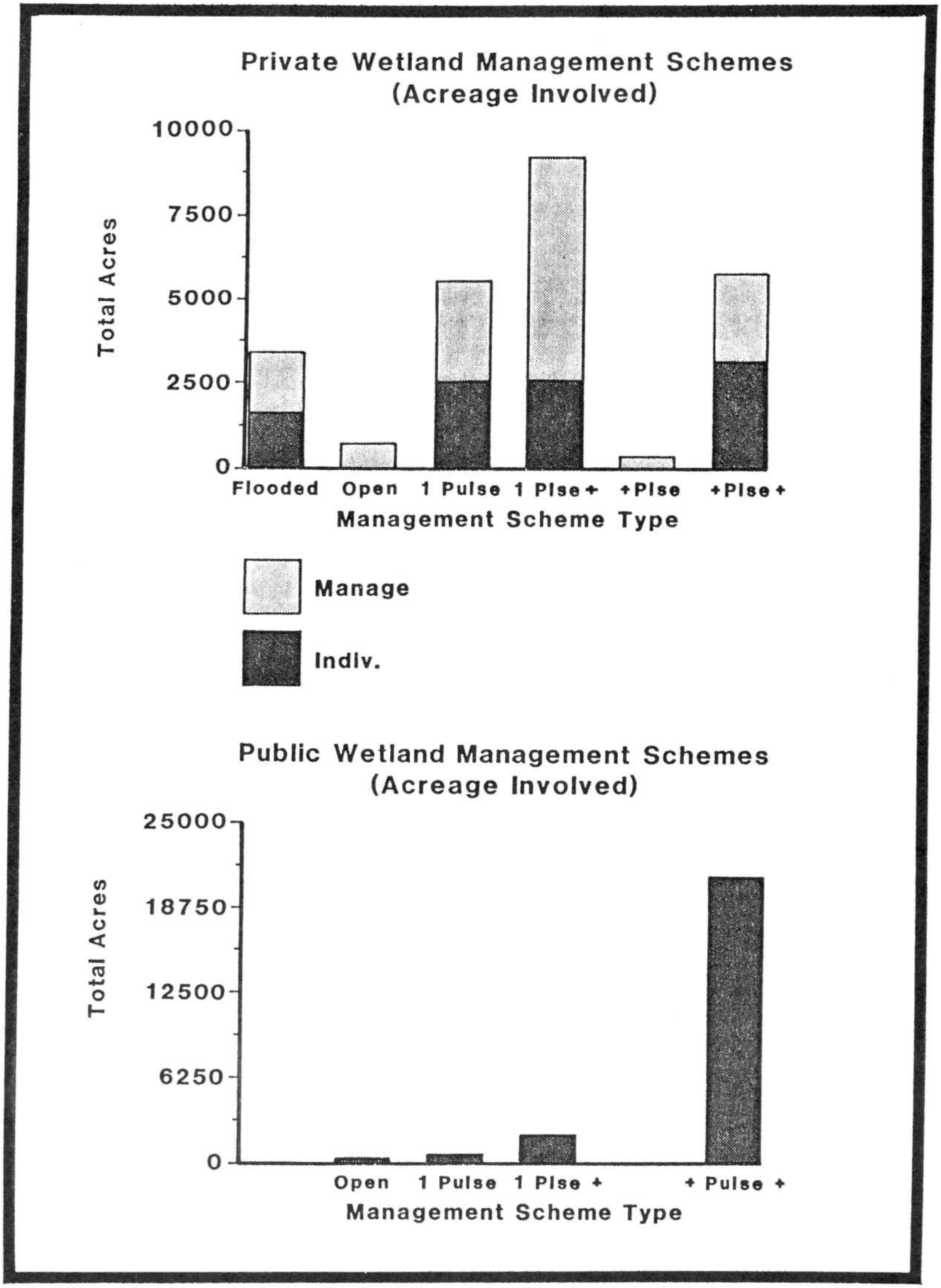



Figure 3. Acreage of private (top) and public (bottom) impoundment sites categorized by management regime. Manage = third party manager; individual = owner/manager.

This short background provides the basis for our workshop today. We will discuss: results of the CWIP as they relate to the management of existing impoundments; management innovations that could possibly minimize potential impacts on adjacent wetland systems; and, most importantly, the need for "GOOD MANAGEMENT" of our existing impoundments in order to maximize their productivity.

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## Overview of the Coastal Wetland Impoundment Project and General Management Implications

Douglas S. Baughman
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Charleston, SC

The SC Sea Grant Consortium initiated the Coastal Wetland Impoundment Project (CWIP) in September 1982 to address a number of the ecological, management and policy questions surrounding impoundments in South Carolina. This four year multi-disciplinary project was designed to examine impoundments in the context of the issues that were being discussed at that time and to gather the first set of comprehensive baseline data on impoundment systems. The primary goal of the CWIP was to provide decisions makers with additional information related to the complex questions concerning impoundments.

The major objectives of the CWIP were to: 1) determine stratigraphy, characterize hydrology, and identify and compare the major floral and faunal components of the impoundments under study; 2) characterize the nutrient dynamics and determine primary productivity of the study impoundments and the adjacent open wetlands; 3) determine and compare the recruitment, growth rates, and standing crop biomass of commercially-important species in impoundments with those in adjacent open wetland areas; 4) determine the flow of nutrients and biomass between the study impoundments and the adjacent open wetland areas; and 5) to determine the public policy issues affecting impoundments: ownership, current and proposed uses, management techniques, and federal and state policy.

The Tom Yawkey Wildlife Center located near Georgetown, SC on the Santee River delta was chosen as the study site because of the availability of multiple small impoundments managed for waterfowl habitat by the SC Wildlife and Marine Resources Department. Specifically, the study site on Cat Island consisted of five impoundments ranging in size from 3.6 to 6.9 ha (8.8 to 17.0 acres) ($\bar{x}$ = 5.1 ha), one unmanaged (breached) tidal impoundment (7.9 ha, 19.5 acres), a larger (13.8 ha, 34 acre) managed impoundment, the open marsh adjacent to the impoundment complex and the adjacent tidal creek, Chainey Creek. Salinities in this area ranged from 0 to 30 parts per thousand (ppt) and averaged around 18 to 22 ppt. Thus, this system was characterized as a brackish impoundment system.

Water management during the study was designed to encourage the growth of aquatic plants, primarily widgeongrass, Ruppia maritima, desirable as waterfowl food. Each impoundment was equipped with a flashboard riser-type water control structure called a trunk which allowed water to be exchanged and water levels manipulated. In addition, each unit was equipped with a spillway to allow water to be circulated between units; however, they were not used during the study due to scientific protocol. The basic management scheme is outlined in Table 1.

The detailed results of the Coastal Wetland Impoundment Project have been compiled into a three-volume technical report (South Carolin Coastal Wetland Impoundments: Ecological Characterization, Management, Status and Use, Technical Reports

(#SC-SG-TR-86-1, 2, and 3). Consequently, for this paper I will concentratate on specific research components and highlight results that particularly relate to the management implications discussed in the following presentations.

The hydrogeology and sediment characteristics of the impoundments, and water seepage through the impoundment bed and dikes, were investigated to determine the possible avenues of water exchange other than through the water control structures. Our primary concern with potential water seepage was to see whether nutrients were being transported between the impoundment and the adjacent creek or between the impoundment and the shallow sub-surface water table. Results indicated that the impoundment sediments were primarily a silt-clay mixture and essentially impermeable. Water analysis of the interstitial waters also confirmed that impoundment waters were not in contact with the shallow water table. Dike seepage studies indicated that although there was some movement of water through the dikes, the volume of this seepage (approximately 598 to 619 liters/day) was insignificant compared to the total volume within the impoundments. These findings suggest that the exchange of water between and among the impoundments and Chainey Creek occurred almost exclusively through the water control structures.

Southeastern salt marshes are well know for their inherent productivity. This productivity has been attributed to the three forms of primary productivity (macrophytes, phytoplankton, and benthic microalgae), daily tidal action, abundant nutrient supplies, conservation and rapid turnover of nutrients, and year round production. To compare the productivity of impoundments and the adjacent open marsh, the study looked at nutrient exchanges between these systems as well as the primary productivity of each floral component.

To compare the exchange of nutrients from the impoundments and open marsh area, water samples were analyzed for ammonia ($NH_4$), ortho-phosphate (o-$PO_4$), and particulate and dissolved organic carbon (POC, DOC). It had been suggested that due to the water management schemes employed in impoundments, they may act as nutrient sinks. Results of this research component suggest that the study impoundments were not significant nutrient sinks. However, the form of the nutrients exchanged and the timing of that exchange in impoundments is quite different from the open marsh system. In impoundments, nutrient exchange is limited to times of water exchange. For example, nutrients were imported to the study impoundments during the spring and summer and exported during the fall and winter with an overall net exchange of near zero. The open marsh, on the other hand, typically exports these constituents on the ebb tide with highest export in the summer and fall culminating in an annual net export. The effects of these differences in nutrient exchange on estuarine productivity can not be determined without additional research.

Phytoplankton production was studied to determine its contribution to total primary productivity of the impoundments and the adjacent open marsh. By monitoring the amount of chlorophyll-a present in water samples, investigators determined that impoundments appeared to be highly favorable habitats for phytoplankton growth. The vast areas of open water and abundant nutrients allowed for high phytoplankton production and, during times of water exchange, high phytoplankton export. In open marsh, phytoplankton typically contributes less to overall primary production. Additionally, it appears that while the marsh exported nutrients in their dissolved organic forms, the impoundments exported nutrients in the form of phytoplankton biomass.

Macrophyte plant communities (marsh grasses) are the major contributors to primary production in salt marshes and play an important role in marsh ecology. Impoundment management regimes for waterfowl are designed to promote the growth of specific macrophytes (e.g., widgeongrass and salt marsh bullrush) while discouraging the growth of others (e.g., Spartina). In addition, previous work on the productivity of southern salt marshes suggested that the daily ebb and flood of the tide provides an energy subsidy which enhances the production of salt marsh macrophytes; impoundment dikes and water control structures alter this tidal flow. Therefore, it was important to compare the macrophyte communities and their production (the second form of primary production investigated) between the impoundments and the adjacent open marsh.

The number of macrophyte species was greater in impoundments than in the open marsh, (19 species versus 3 species); largely due to the influence of the water level management scheme employed in the impoundments. Comparisons of total (all species combined) macrophyte productivity showed that there was no significant difference between impoundments or between the impoundments and the adjacent open marsh. However, the primary target plant species, widgeongrass, peaked in biomass by late summer in both years and was not available for migrating waterfowl. Unusually high water temperatures and salinities were probably responsible for the decline in widgeongrass during the summer months, which suggests that alterations in the management scheme may result in more biomass available for waterfowl in the fall.

Benthic microalgae (BMA) - small diatoms and plants that live on or in the bottom sediments - also contribute to overall primary productivity in coastal habitats. Due to the extensive shallow mud flat areas in impoundments, it was suggested that benthic microalgae may be highly productive in these areas. The preliminary studies, although not conclusive, do support this claim. Production of BMA in the impoundments approached levels recorded for similar coastal habitats.

Overall, comparing all three forms of primary production, the data indicate that the impoundments and the adjacent open marsh were not significantly different. However, the relative contributions of phytoplankton, benthic algae and macrophytes differed between systems. In the tidal wetland, primary production was dominated by emergent macrophyte vegetation, while submerged macrophytes, benthic algae, and phytoplankton were the significant producers in the study impoundments.

The abundance and biomass of zooplankton (planktonic animals) in the impoundments was determined and compared with that of the adjacent tidal wetland creek. Zooplankton feed on phytoplankton and are in turn fed upon by larval and juvenile fish and crustaceans, making them an important link in the estuarine food web. Results of this component indicated that the standing crop of zooplankton was greatest during periods of reduced water exchange, coinciding with the period of peak phytoplankton production. During periods of greater water exchange, the numbers of zooplankton in the impoundments decreased to levels similar to the adjacent creek. In general, zooplankton densities were similar to other coastal habitats but zooplankton blooms recorded during this study suggest that under certain conditions impoundments may produce higher densities than open tidal systems.

The species composition, density and population dynamics of invertebrate macrofauna were also compared between the two systems. Macrofauna in this study included small benthic crustaceans, insects, worms, and mollusks, as well as blue crabs and shrimp. Benthic macrofaunal community composition and structure was found to be significantly different between analogous sites in the impoundments and the adjacent marsh. Comparisons of the vegetated sites, for example, indicated that the impoundments contained fewer species than the open marsh sites. These differences appear to be due to environmental factors (low dissolved oxygen and high temperatures) and predation by waterbirds. Shallow water levels and reduced water circulation may promote these conditions.

Investigations on utilization of the impoundments and adjacent marsh by shrimp and crab suggest that the dikes and water control structures do affect their use of impoundments. Access to the impoundments depended on the timing of recruitment for a particular species and the periods of water exchange. For example, larval and juvenile brown shrimp appeared in the tidal creek during May and June when there was moderate tidal exchange in the impoundment. As a result, they were recruited into the impoundments. Pink shrimp, on the other hand, are present in the area during late summer (July-September) when there is little water exchange and therefore, are not recruited into the impoundments. Furthermore, the migration of shrimp into the impoundments exceeded emigration out of the impoundments. Only 7.6% as many shrimp were caught leaving as entering the impoundments. These data illustrate that management strategy is the key to the degree of impacts on estuarine crustaceans. The volume, timing and method of the water exchange will determine utilization of the impoundment by shrimp and crabs.

Fish community composition, structure and seasonal abundances were also determined and compared between the impoundments and adjacent tidal marsh creek. Results indicate that trends for the fish community are similar to those for the crustaceans. That is, recruitment of larval fishes was also dependent on the timing of water exchange and the natural recruitment of a species. Spot, for example, were the dominant larval fish caught during the study and were recruited during a period of little water exchange. Therefore, of the 29,500 individuals collected, 28,000 were caught in the adjacent tidal creek; very few spot were caught entering the impoundments.

Data also indicate that there was a distinct difference in the composition of the fish communities in the impoundments and the adjacent open marsh. Impoundments were dominanted by mosquito fish, Gambusia affinis , while the mummychog, Fundulus heteroclitus was the dominant species in the tidal creek. These differences could be attributed not only to the recruitment patterns reported above but also to the stressful environmental conditions (high temperature and low dissolved oxygen) that occurred during the summer months of low water exchange. Stressed fish became lethargic and were easy prey for both waterbirds and alligators. Thus, only those fish species that were able to tolerate these conditions were able to adapt to the impoundment environment. Increased water circulation may have reduced these stressful conditions.

Waterbird utilization of the impoundments and open marsh was also compared; waterfowl was the primary target of the management scheme used during the study. Not surprisingly, the managed impoundments were used by higher numbers of waterbirds and more diversified waterbird assemblages than the unmanaged marsh sites. Overall utilization was dominated by shorebirds (54.8%) followed by waterfowl (26.8%). The interesting point to note on the waterbird studies is that the managed units provided a more attractive habitat for numerous water bird types, not just waterfowl. This may have been due to the extensive mudflats and shallow water available in the impoundments to wading and shore birds for feeding.

## BASIC ECOLOGICAL CONCLUSIONS

The impoundment and open marsh systems were different with respect to the overall community structure of several major biological components (macrophyte plants, macrobenthic invertebrates, and fishes), however, the basic ecological processes were similar. This study suggests that the major differences between the two systems are a function of "water transfer effects" - the alteration in tidal flow and water exchange. Consequently, the management scheme employed will influence the way a species is able to adapt to and use the impoundment system. Intensive management provides a way to minimize these "water transfer effects."

## MANAGEMENT IMPLICATIONS

The Coastal Wetland Impoundment Project (CWIP) examined the ecological characteristics of a brackish impoundment system subjected to a single, but typical, management strategy designed to provide habitat for waterfowl. Results from this study are specific to this site and can not be extrapolated to impoundments of larger size, other salinity regimes, or other management schemes. However, there are trends and patterns which have been highlighted in this research that will apply to most managed impoundments and serve as the basis for the following outline of management implications.

Enhancement of Impoundment Management for Target Species.

Although the management scheme employed during the CWIP was highly successful in providing habitat for migrating waterfowl and other wildlife, the biomass of widgeongrass peaked in late summer and was not available for ducks in the fall. As mentioned earlier, this situation was probably due to the high salinities and temperatures experienced during the summer. Flooding the impoundments later in the year, such as June-July, may delay the peak of widgeongrass until October or November when it would could be eaten by waterfowl. Also, increased flow of freshwater from an upland reserve pond may help to decrease salinities and maintain the widgeongrass crop a little longer.

The potential for managing impoundments for other wildlife has also been documented during the CWIP. Bob Joyner, later in the workshop, will present information on multi-species utilization of impoundments during the CWIP and other management considerations for non-game wildlife. Additional research sponsored by the Consortium has demonstated the potential for extensive shrimp culture in impoundments. By delaying the time of flooding to the period of maximum larval densities in the adjacent tidal creeks it is possible to selectively recruit naturally-occuring penaeid shrimp. The success of this type of extensive culture is dependent on the circulation of at least 10% of the impoundment water volume each day, but more importantly, on the availability of shrimp larvae in the water column. If the shrimp are not available during the flooding process then they will not be recruited into the impoundment. Jack Whetstone will discuss aquaculture in impoundments in more detail later in the workshop.

Enhancement of Water Quality Conditions. The water quality conditions (e.g., temperature, salinity and DO) in impoundments, may become stressful to many estuarine species during the summer months of low water circulation. In this study, these conditions adversely affected benthic macrofauna, fish and crustaceans. Greater water circulation throughout the summer may reduce the threat from these conditions.

Enhancement of Non-target Species Migration. Results of this study suggest that one of the primary impacts of impoundments on marsh processes is the barrier that dikes present to larval and juvenile stages of estuarine fish and crustaceans. By altering specific management techniques to improve water circulation and timing it may be possible to minimize these impacts.

Mosquito Production and Impoundment Management. Although the CWIP did not specifically address mosquito production, techniques were used to reduce mosquito breeding in the study impoundments. This involves a drawdown-reflood cycle that removes hatching mosquito larvae from the impoundment beds during the flooding cycle and makes them available to small fish. Such management alterations can significantly reduce mosquito production in brackish impoundments.

These four implications have been summarized from the results of the CWIP and are the basis for this workshop. The following presentations will suggest specific management techniques to address these concerns.

# Dikes and Water Control Structures: Repairs, Maintenance and Potential for Management

R. Kenneth Williams
Kinloch Plantation

## TIDAL IMPOUNDMENTS IN SOUTH CAROLINA

There are presently some 70,000 acres of tidal impoundments in South Carolina. Most of this acreage is located in areas of tidal freshwater wetlands that were formerly developed for the culture of rice during the eighteenth and nineteenth centuries. There are, however, a representative number of impoundments in newly-diked brackish and saline tidal wetlands. Additionally, some 74,000 acres of old ricefields exist that have fallen into disrepair and no longer function as impoundments.

Most tidal impoundments are managed to attract wintering waterfowl. Some impoundments are used for aquaculture, while some are multi-purpose and used as combination cattle-grazing/waterfowl or aquaculture/waterfowl impoundments.

Before proceeding further, the term tidal impoundment should be defined. For purposes of this paper, the term tidal impoundment shall mean any area of tidal wetland enclosed by an earthen dike along which various water control structures have been installed for draining or flooding of the area. Perhaps a more appropriate definition of tidal impoundment would be managed or manageable tidal wetlands. Indeed, it is the inherent manageability of tidal impoundments that adds to their uniqueness and importance among coastal ecosystems.

The South Carolina Sea Grant Consortium questionnaire sent to all impoundment owners in South Carolina produced some interesting information. The questionnaire results indicate that tidal impoundments in South Carolina exist in various states of repair and management potential. The respondents reported that 34,000 acres of impoundments exist that are in functional condition, i.e., dikes and water control sturctures are intact and operable. Some 16,300 acres exist that need to have dikes repaired or water control structures repaired or replaced to be functional. Surprisingly, over 3000 acres of impoundments had no potential for tidal exchange. The total acreage reported is less that 70,000 acres (as previously mentioned), because not all landowners responded to the questionnaire.

## DIKES AND WATER CONTROL STRUCTURES - REPAIRS AND MAINTENANCE

### Dikes

The results of the Sea Grant questionnaire indicate that some information should be available to the public (landowners) regarding repairs and maintenance of existing impoundments and water control structures that would allow for upgrading the physical features of tidal impoundments and improve on their functioning and management potential.

Modern dikes are constructed and maintained by use of the dragline dredge or hydraulic trackhoe. These machines must necessarily work off of wooden mats for safety and stability. As previously mentioned, most presently existing impoundments were constructed in the old ricefields. The dikes used to enclose these areas were usually constructed atop the old ricefield dike, although some did not follow those courses exactly. Also, it has been mentioned that some impoundments have been constructed in brackish and saline wetlands that were not former ricefields.

Modern dikes may vary in dimension depending upon whether or not they are to be driven upon. The dike that is be driven upon should be at least 12′ wide on the top surface. The width from heel to toe, i.e., the base of the dike, should be at least 25′ to 30′. Dikes that are not to be used for travel with motor vehicles may be proportionately smaller in top surface width and base width.

The most important dimension to consider for any dike is the height. All dikes should be at least 3′ above mean high water at the various locations along the South Carolina coast. Keeping in mind that tidal amplitudes increase from North to South along the coast and decrease as you proceed upstream in tidal rivers, it is recommended that the mean high water mark be located using a surveyor′s level. The dragline or trackhoe operator repairing the dike would then be able to construct the dike according to the vertical gradient determined by the surveyor′s level. Dikes constructed at 3′ above mean high water would be capable of withstanding all but storm surges during hurricanes, catastrophic floods, or phenomena such as a syzygy. (A syzygy increases tidal range when the earth, moon and sun are in line.)

The term "topping" is used to describe the excavation of material to be placed on dikes that are too low or that have settled below grade. Dikes should be topped high enough to allow for shrinkage and settling as drying occurs so that the net height would be 3′ above mean high water. The machine operator will be able to identify the best soil material at each site as the machinery progresses around the dike. Clay base soils are best for dike repairs. The operators may encounter peat or sandy soils in some areas. If the material being excavated for dike repair has a high sand content, it may be necessary to key the dike to prevent erosion of or leakage through the dike. Keying refers to excavating a trench in the center of the dike, which is filled with impervious soils such as clay. Soils with high clay content may have to be brought in for keying if unavailable at the construction site.

Modern dikes should be constructed of materials excavated from a borrow pit or canal on the inside of the impoundment. The berm, or area between the base of the dike and the borrow pit, should be left as wide as the machinery being used will allow. Leaving extra width will allow for subsequent passes around the dike when and if future topping becomes necessary to keep the height up to grade.

Stoppages are constructed at points where the course of the dike is intersected by small tributaries or canals. Those points may need bulkheading with treated pilings and lumber for added strength.

After drying and settling (usually 3 to 6 months), the dike should be graded to uniformity along its entire length. The top surface of the dike should be graded to leave a slight rise in the middle to allow rainfall to run off without damage to the surface. To further protect the top surface of the dike, it is advisable to topseed with grasses, such as bahiagrass or

Bermudagrass, to retard erosion. Certain soils such as catclays that become acidic after drying may require topping with a layer of sand before grasses can be established. Do not encourage large shrubs or trees to establish on the dike since root systems of this type vegetation may damage the dike if uprooted during a windstorm.

Water Control Structures

Water control structures, sometimes called trunks, are employed to drain and flood tidal impoundments. The structures may be constructed of wood, metal, or concrete and vary considerably in design, size, and function. It is of utmost importance to have a structure designed to accommodate the physical features of the area and the objectives of the management plan. That is to say, the trunk should fit the situation by design, size, and function.

Concrete structures are not in common use in South Carolina tidal impoundments. After installation, these structure often settle unevenly in the unstable substrate of tidal wetlands, thereby affecting their proper functioning. These structures will likely present more problems than they are worth. Consequently, they are not recommended for use in tidal impoundments, especially since other types of water control structures are available.

Metal trunks, usually constructed of heavy gauge aluminum or steel, are in common use in South Carolina, particularly in totally freshwater areas. Metal structures may consist of a length of corrugated pipe 36 inches in diameter (generally) and vary in length from 20′ to 40′. Metal trunks may have a flapgate on one end and a flashboard riser on the other or they may have flapgates on both ends with an associated flashboard riser. One very popular configuration consists of a structure with a flapgate on the outside end, a combination flapgate/screwgate on the inside, and an associated flashboard riser on the inside end.

Metal trunks are quite functional in moving water or stabilizing water levels at a preset level. There are some problems with metal structures that should be noted. First of all, the concave or slotted flapgate normally built into these structures may cause difficulty when attempting to manipulate them except on a slack tide or a low head of water pressing on the flapgate. Also, metal structures may rust or corrode in even slightly brackish waters. Metal trunks also tend to become clogged with waterborne debris such as roots, logs, and aquatic vegetation. This debris would have to be physically removed from the structure.

Trunks constructed of pressure-treated wood, either creosote or copper chromate arsenic, are also in common use in South Carolina. Wooden trunks, like metal structures, are also constructed with various configurations. The typical wooden trunk consists of a wooden box 2′ high x 5′ wide, and either 28′ or 36′ long. These trunks usually have two sliding flapgates or doors and a wooden flashboard riser or spillway attached to the box. Other designs include structures with two sliding flapgates and no riser, or a sliding flapgate on one end and a riser on the other end. Various dimensions, other than the standard 2´ x 5´ are also in use. Trunks measuring 1´ x 4´ x 28´ and 2´ x 4´ x´ 28´ or 36´ are common.

As stated, these wooden structures are constructed using pressure-treated creosote or 2.5 pound CCA lumber, usually pine. Hot-dipped galvanized nails and bolts may be used in the building of trunks to be installed in strictly freshwater tidal areas. For the sake of longevity, stainless steel nails and bolts are recommended for building trunks to be used in brackish or saline zones. Where the trunk extends beyond the bulkhead, bottom boards of the box are generally a weak spot and should be fastened on with stainless lag screws or treated pegs and nails. Also, scabs can be added to the side of the box so that nails can be driven into the ends of these vulnerable bottom boards.

Generally, wooden trunks can be manipulated on any tide using the sliding flapgates. Due to their rectangular openings, these structures do not often become clogged with debris. Creosote-treated wooden trunks have withstood the test of time. Some wood rot and marine borer damage has been reported in the CCA-treated wooden trunks, where the wood did not accept the pressure treatment adequately or was not treated at the 2.5 pound level.

All trunks, be they concrete, metal, or wood, should be installed perpendicular to the course of the dike and with the bottom of the structure at, or slightly below, the mean low water mark at the installation site. Again, a surveyor´s level may be used to ascertain the mean low water mark. A bulkhead should be constructed using treated pilings and lumber to hold the control structure in place. Trunks and bulkheads require periodic maintenance if they are to continue to function properly. Flapgates and hardware should be inspected regularly so they may be repaired or replaced when necessary.

Bulkheads may backwash while flooding or draining is taking place. Pilings and sheeting boards in the bulkhead should be replaced as they show signs of deterioration. Replace the backfill in washouts and caveins behind bulkheads when they occur; otherwise, the entire structure may by undermined and eventually wash out. Any small cracks in the bulkhead must be plugged to avoid the slow loss of fill material which causes cave-ins.

Metal trunks in current use are subject to rust and corrosion in areas with even small amounts of salinity. Parts of metal structures exposed to the atmosphere can be visually inspected for repair or replacement. If the culvert portion of a metal structure begins to leak, the entire structure may have to be removed for repair or replacement. Collars attaching culverts to stubs should be two feet wide and bolts used should not be susceptible to catalytic action. The stub should be long enough to extend well into the bank to give extra support.

Trunks constructed of pressure-treated wood last longer than metal trunks in current use. Many wooden trunks in use today have been in place and operable for thirty years or longer without replacement. However, when wooden trunks fail to function properly or become disabled, these structures can be carefully removed from the dike for repair and re-installation. Often, all that is needed for restoring the wooden trunk to full serviceability is replacement of a few boards or hardware.

When a trunk has to be removed for repair or replacement, it is common practice to move a few feet down the dike away from the old installation point. Trunks installed at the old installation site may settle unevenly and become non-functional. Trunk installation should be avoided in sandy-bottom sites or the trunk should be bedded in impermeable clay and the bulkhead lined with clay.

Cost of Repairs and Maintenance

Cost of dike repair and maintenance varies from operator to operator and from region to region. Dragline or trackhoe owner/operators may be employed to work by the hour or by the job. Presently, dragline owner/operators are charging from $35.00 to $65.00 per hour of operation. Trackhoe owner/operators are charging from $65.00 to $75.00 per hour of operation. These machines vary in size and speed of operation. Generally, the trackhoe operators can construct more linear feet of dike per day than can the dragline operator.

Costs per linear foot of dike using a dragline dredge would average between $3.00 and $5.00 depending on how may vertical feet of topping is necessary to bring the dike up to grade. Trackhoe costs would be closer to $2.00 to $3.00 per linear foot for the same type of excavation.

There are no figures for repair and/or replacement of concrete water control structures. Parts of metal structures (such as flapgates or risers) may be repaired or replaced. Costs would vary according to availability and manufacturer. Presently, a standard metal trunk 36" in diameter and 36′ in length with two flapgates and a riser would cost approximately $5,000.00 to replace. Installation costs (including bulkhead) would range between $2,000.00 and $2,500.00.

Repair costs for wooden trunks would vary with the price of treated lumber and the price of galvanized or stainless steel hardware. Replacement cost for the standard wooden trunk of 2′ x 5′ x 28′ or 36′ dimensions would be between $4,000.00 and $4,500.00 for building materials only. Installation costs (including bulkhead) would range between $2,000.00 and $2,500.00. These estimates do not include the labor fee to construct the wooden trunk.

POTENTIAL FOR MANAGEMENT

Several questions come to mind when considering upgrading management in a tidal impoundment:

1. How does the size of the impoundment relate to management potential?

In South Carolina, existing impoundments range in size from less than an acre to several thousand acres. Generally, larger impoundments, i.e., those of 200 acres or more, would be more conducive to management for wintering waterfowl. Smaller impoundments would likely be more conducive to the many exacting requirements necessary for aquaculture.

Cross-diking (or subdividing) large impoundments is an alternative worth considering if this would increase management potential on an area.

2. How does the size and design of the water control structure affect management potential?

The size of the structure is important. If there is any doubt that the structure being considered can accomplish management goals, always consider installation of a larger structure. Obviously, smaller trunks may adequately serve small impoundments. But, when considering that rapid, high-volume movement of water is often desirable for one management practice or another, the larger structure would be the best alternative. The standard 2′ x 5′ x 28′ or 36′ wooden trunk is often recommended.

When considering design, the ideal control structure would be a trunk that has two flapgates and an associated flashboard riser. These trunks allow for flooding and draining the impoundment with a minimum of effort. Structures of this design will control water levels automatically once they are adjusted. The riser structure allows for discharge of waters above a preset level independent of the flapgates.

Flashboard riser structures that have no flapgates may be installed in cross-dikes to aid in circulation of water between adjacent impoundments.

3. How many water control structures are necessary for proper management?

On larger impoundments, one trunk for each 150 acres should be installed for proper management. Flashboard riser structures in cross-dikes between adjacent impoundments may be counted in the formula. On impoundments of 150 acres or less, at least two structures should be installed if the location of the dikes in relation to adjacent tidal tributaries or adjacent impoundments is such that this would be possible.

4. How does the installation of the control structure affect management potential?

When installed at, or some four to six inches below, the mean low water mark, a trunk will allow for complete drainage or flooding of the impoundment with proper manipulation of the trunk flapgates. The ability to manipulate water levels is a very important management tool.

5. How does the location of the control structure affect management potential?

Proper location of the trunk in relation to adjacent tidal waters is extremely important. Keeping in mind that water quality (e.g; freshness or salinity) is one consideration in managing plant communities in an impoundment, the manager should be aware that varying degrees of freshness or salinity may occur at different points around the tidal perimeters of the dike. Trunks should be located to best serve management schemes dictated by water quality variances in a particular area.

When upgrading management plans for particular areas and types of management, it is feasible to consider the relocation of control structures on a tidal impoundment to increase management potential. Moving a trunk a few hundred feet along the perimeter dike may increase management potential tremendously.

## CONCLUSIONS

A system of sound dikes constructed to withstand all but castastrophic events and well-designed, well-constructed, and properly-located water control structures are absolute necessities when addressing the many physical and chemical factors affecting management in a tidal impoundment.

Sound management should be an on-going, full-time responsibility of the landowner and land manager. Upgrading management potential should be a priority consideration when practical, feasible, and affordable.

# Methods to Enhance Target Species Production in Freshwater Impoundments

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Thousands of acres of freshwater wetlands along coastal South Carolina were in rice cultivation during the 19th century. Former ricefields have been a principal reason that South Carolina ranks high in the Atlantic Flyway in numbers of wintering waterfowl (Gordon et al., 1987). Traditionally, large concentrations of local and migratory waterfowl have used coastal wetlands annually. Shallow water and abundant food sources provided in well managed freshwater impoundments have attracted and supplied the waterfowl resource and have furnished substantial sport hunting opportunities for many years.

Most suitable tidal freshwater wetlands in South Carolina were diked and under water control for rice production and were the principal rice production areas of the United States preceding 1900 (Rogers, 1970; Kovacik, 1979). A number of these areas maintained some degree of function as rice plantations after 1900 and were recognized as important waterfowl wintering habitat during the early 20th century as rice culture dwindled. Private landowners thereafter undertook efforts to redevelop and manage former ricefields as waterfowl hunting areas (Conrad, 1966; Miglarese and Sandifer, 1982; Prevost, 1987). Freshwater tidal wetlands formerly under rice cultivation were important to the waterfowl resource prior to the development of techniques for managing brackish or saline wintering habitats. Managed, freshwater tidal wetland impoundments have been particularly important wintering habitat for wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), northern pintail (*A. accuta*), and green-winged teal (*A. crecca*).

Diked and managed tidal fresh marsh impoundments have been described by a number of investigators (Conrad, 1966; Morgan et al., 1975; Miglarese and Sandifer, 1982). Vegetation in managed freshwater impoundments is dominated by target species that are adapted to conditions stimulated by prescribed wetland management objectives. Herbaceous plants of the early successional stage are target species for wintering waterfowl habitat management in freshwater wetlands. Many of these species are copious seed producers. In some cases, waterfowl seek tubers of certain plants over seed or vegetative matter. These early successional stage macrophytes produce seed or vegetative parts documented as food sources for many dabbling ducks (Conrad, 1966; Kerwin and Webb, 1972; Landers et al., 1976).

Impoundments in the freshwater tidal zone offer perhaps the greatest capability for enhanced wetlands management as waterfowl habitat due to high productivity and diversity. Typically, freshwater impoundments in coastal South Carolina are small and potentially easily managed as compared to brackish systems where salinities have to be constantly monitored. In these wetlands, however, there may be the lowest overall effort of management and correspondingly the lowest yield in resource productivity and benefit. Freshwater coastal impoundments are smaller, more affordable, and annual management costs are such that most ownership and management is often absentee in nature. Many owners maintain part-time employees performing as watchmen with little active involvement or expertise in wetland management. However, with persistence and attention to detail, owners and managers can effectively enhance both production of desirable plant species and also movement of transient aquatic organisms in these areas.

Wetlands management for wintering waterfowl habitat is a land use form compatible with the basic functions of wetlands. This type land use can be an alternative for naturally functioning wetlands, and is preferred to alterations for many other purposes. Impoundment management techniques can be meshed with natural wetland processes to include a controlled flow of aquatic organisms and nutrients into and out of managed freshwater wetlands.

Wetlands management in freshwater impoundments as in other coastal wetland habitats is facilitated by the use of water control structures (trunks) connecting impoundments with surrounding tidal water. By properly employing trunk settings, managers can utilize a variety or combination of settings of doors and riser heights to regulate or circulate water levels within freshwater impoundments. This can be done through incremental adjustments on doors providing water exchange as directed by management objectives. Adjustment of doors and riser heights by knowledgeable managers is the means to achieve desired soil moisture levels in freshwater impoundments that enhance growth and maintenance of target plant species.

Managers can produce desirable quantities of certain smartweeds (*Polygonum* spp.), Asiatic dayflower (*Anelima keisak*), spikerushes (*Eleocharis* spp.), various grasses (Grammineae), and sedges (Cyperaceae) in tidal fresh impoundments having moderate to high mineral soil content and moderate acidity. These species are adapted to moist soil management ranging from a very wet bed to a moderately dry bed. Redroot (*Lacnanthes caroliniana*) and warty panic grass (*Panicum verrucosum*) are adapted to soils of high organic matter and correspondingly low mineral content and high acidity where soil moisture levels are high throughout the growing season. All of these target species respond well to and tend to be most productive after disturbance. Fire is the most commonly prescribed technique for disturbance (Lynch, 1941; Yancy, 1964; Hoffpauer, 1967). Other techniques used for disturbance include mowing, grazing by livestock and mechanically turning soils using farm machinery (Neely, 1967).

Permanently flooded freshwater impoundments can produce a variety of early successional stage submerged and emergent aquatics which are important to waterfowl (Kerwin and Webb, 1972; Landers et al., 1977; Prevost, 1987). Most noteworthy among these include Schreber watershield (*Brasenia schreberi*), white waterlily (*Nymphaea odorata*), pond weeds (*Potamogeton* spp.), and common hornwort (*Ceratophyllum demersum*).

Preferred moist-soil management techniques employed in fresh tidal impoundments are initiated in late winter or early spring when impoundments should be thoroughly dewatered. Drying allows desirable oxidation of organic matter and prevents

Virginia arrowarum (_Peltandra virginia_) and golden club (_Orontium aquaticum_) from becoming robust enough to become dominant. Moisture levels should be carefully increased to the point of creating a soggy, spongy substrate during late April. Increases in soil moisture at this time will stimulate desirable plants on a previously disturbed marsh bed. While smartweeds and Asiatic dayflower are tender and small, managers should use care that the marsh not become flooded for a period sufficient to smother and kill these sprouting plants. To continue the encouragement of desirable plants, soil moisture must remain high throughout the growing season. Grasses and sedges will be encouraged with dryer soils. Cattails (_Typha_ spp.) and giant southern-wildrice (_Zizaniopsis miliacea_) can become established if soils are maintained excessively moist for several years. Woolgrass bulrush (_Scirpus cyperinus_) is normally a good indicator of soil moisture levels that are too high in fresh wetlands. Plume grass (_Erianthus giganteus_) is noted as an indicator species of conditions that are too dry to produce preferred plant species.

Desired soil moisture levels can be achieved by maintaining static water levels at or near marsh level throughout the growing season. Static water level management can degrade impoundment water quality since water exchange within ditch networks is negligible. Rapid growth of emergent plants in perimeter ditches usually follows in management schedules which adhere to static water level management in freshwater wetlands. Static water levels deter the ability of aquatic organisms to enter and leave freshwater impoundments.

The alternative to static water level management in freshwater tidal wetlands managed for moist-soil plants requires the use of tidal energy to circulate water within ditch networks. This technique obligates strategic placement of water control structures, and a rigid adherence to schedules of trunkminding. In this strategy, the outside or tidal doors of trunks are kept partially open during the growing season to allow for inflow on high tide. Water circulates within impoundment ditches causing reduced internal tides and is flushed out partially opened doors or over flashboard risers on low tides. Trunk adjustments are often required several times each week to compensate for water levels outside the desirable range. Properly done, this technique can result in desired moist soils. Water quality is greatly enhanced with this practice as it allows for a twice daily partial exchange of water into and out of impoundments. During periods of vigorous circulation, managers can effectively discharge floating mats of undesirable vegetation that otherwise choke ditches and preclude drainage and access. Aquatic animals are provided with enhanced opportunities to more freely move into and out of managed wetlands where management strategies employ some type of water circulation. This type management also coincides with periods of growth and reproduction of almost all aquatic organisms thereby providing available habitat during periods of increased energy and protein requirements.

In September, managers should drain freshwater impoundments. Plant maturity and seed production is hastened by drying. Drying also prepares the marsh for burning in November.

Burning should be prescribed after first frosts. Cool dry weather and dry marsh conditions may permit burning prior to frost. Patchy burns that produce irregularly sized and shaped openings are ideal and when flooded provide a mixture of open water and cover. Complete burns that remove almost all vegetation will result in too much open water when flooded and resource utilization may be less than expected.

Burning should not be attempted in freshwater wetlands with highly organic soil content due to risk of physically setting the peat substrate on fire which can seriously damage wetlands. Peat fires can remove enough soil material to cause sufficient subsidence in marsh elevation which can later reduce management potential on the site.

Burning freshwater impoundments can provide advantages in future wetland management and resource utilization. Fire retards plant succession and maintains the desired successional stage for successive growing seasons. Burned marshes have open water areas after flooding. Fire consumes vegetative portions of plants and deposits seed material to the marsh floor for waterfowl utilization. Crippling loses during harvest periods may be reduced due to more relative retrieval ease. Fall burning is compatible with moist soil management for the target plant species.

After burning, freshwater impoundments should be flooded to an average depth of 22 cm. This depth produces water level ranges from 15 to 30 cm and will provide available habitat for a variety of waterfowl species. Every effort should be expended to maintain this depth to provide for optimum utilization strategies. Fluctuations from ideal utilization depths can cause ducks to leave an impoundment with abundant food supplies. Maintenance of proper water depths to ensure waterfowl utilization in winter is one of the most often neglected duties of the waterfowl habitat manager.

Fredrickson and Taylor (1982) outlined many reasons for managing wetlands for naturally occurring food sources as opposed to production of row crops. Their comparative conclusions should be taken into account when considering strictly agricultural operations in freshwater wetlands. In freshwater impoundments, management for cereal grains is not only possible but also practiced by many landowners. Various ecological and physical problems may result from planting wetlands and affect the health and managability of the habitat. Waterfowl resource welfare is not enhanced with such strategies since cereal grains fail to provide essential physiological requirements. The monetary costs of implementing agricultural activities in wetlands is high. Tall dikes, deep ditches, pumps, additional conventional water control structures, and the use of chemical pest agents have to be considered. The basic requirement of maintaining dry sites for agricultural applications precludes manipulation of trunks to enhance movement of aquatic organisms. In fact, a broad and desirable assemblage of invertebrates, amphibians and reptiles generally are excluded from movement into such sites.

The costs of managing for naturally occurring food sources are insignificant as compared to row crop production in wetlands.

The benefits of managing for target vegetation with a strategy that potentially maximizes movement and thus utility of present aquatic and terestrial species are obvious and well known to wildlife professionals.

Freshwater tidal impoundments are an important component of the South Carolina coastal zone, and have played a key role in waterfowl habitat management for nearly 200 years. As the complex relationships involving impoundment utilization and management are better understood, improved techniques for stewardship of these habitats can be employed by managers. Procedures that enhance circulation in freshwater impoundments without compromising production of desirable macrophytes enhance the ability of aquatic organisms to more freely move from impoundments to surrounding tidal waters.

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## Management To Enhance Target Species Production in Brackish and Saline Impoundments

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Managed brackish marshes provide vegetation structure and food resources valuable to migratory waterfowl and other wetland wildlife species. These wetlands provide cover and resting sites; however, food production is important to their value as waterfowl habitat (Gordon et al., 1987; Gray et al., 1987). Seeds, vegetative portions, and tubers of naturally occurring plants supply diverse nutritional resources utilized by waterfowl to meet their physiological requirements during migration and wintering periods (Fredrickson and Taylor, 1982).

Historically, the most successful water management schedule for food production in brackish marshes in South Carolina has involved a complete drawdown in early spring (March) for 4 to 6 weeks. This is typically followed by a shallow reflooding in early to mid-April and a gradual elevation of water levels throughout the remainder of the spring and summer until maximum depths are achieved in mid to late August.

Specific assemblages of plant foods encouraged by this management regime include saltmarsh bulrush (*Scirpus robustus*), dwarf spikerush (*Eleocharis parvula*), and widgeongrass (*Ruppia maritima*). Saltmarsh bulrush, a perennial, reproduces primarily from rhizomes and sprouts on areas of higher elevation soon after the spring drawdown. It produces an abundance of large seed that are utilized extensively by numerous species of ducks, particularly mallards (Anas platyrhynchos) and northern pintails (A. acuta). Maximum seed production occurs in areas with water salinities of 3 to 7 ppt. Dwarf spikerush grows best on sites with water salinities of 5 to 20 ppt and the groups of individual plants form a turf-like mat of vegetation on mud flat areas. Green- and blue-winged teals (A. crecca and A. discors) feed on the diminutive spikerush seeds, northern pintails grub for the tubers, and American wigeons (A. americana), gadwalls (A. strepera) and coots (Fulica americana) feed extensively on the stems. Upon reflooding, widgeongrass germinates and develops into large stands of submersed vegetation in open water areas. The most successful management of widgeongrass generally occurs within a salinity range of 10-20 ppt. The vegetative portions of widgeongrass are important to northern pintails, American wigeons, gadwalls, and coots. Widgeongrass seeds are consumed readily by northern pintails and teals (Neely, 1962; Kerwin and Webb, 1972; Landers et al., 1976; Prevost et al., 1978).

Although this system of management generally has produced quality habitat conditions for migratory waterfowl, several limitations associated with specific aspects of waterfowl habitat, multi-species use, and general wetlands management consistently have been noted. Standing crops of widgeongrass biomass frequently have declined significantly in late summer and consequently are largely unavailable to migratory waterfowl. These declines have been directly associated with infestations of filamentous algae (Cladophora spp.) when widgeongrass plants form mats on the waters surface (Prevost et al., 1978) and die-offs of widgeongrass attributed to stressful growth conditions in late summer (Percival et al., 1970; Swiderek, 1982). Additional concerns have been expressed related to potential for production of salt marsh mosquitoes (Aedes sollicitans and Aedes taeniorhynchus) that deposit their eggs on moist soil. Extended complete drawdowns generally result in substrate characteristics (moisture and pH) which are conducive to large scale egg deposition. Significant salt marsh mosquito production may occur in 5 to 7 days when managed marshes are inundated by intentional tidal flooding or rainfall (Vorgetts and Ezell, 1978; Tidwell, 1984). A third area of concern centers on marine organism migration and impacts of water quality on estuarine invertebrates and fishes. Manipulation of trunk doors and spillways, to accomplish traditional management strategies, have been cited as creating physical barriers limiting recruitment and emigration of transient estuarine species. In traditional management regimes, a decline in water quality (low dissolved oxygen and high temperatures) also may be experienced in late summer when water circulation typically is minimal (DeVoe et al., 1986).

In recent years, management schedules, on various properties, have been modified to delay the spring drawdown and reflooding processes so as to result in maximum widgeongrass standing crops occurring during fall periods, thereby providing maximum benefits to migratory waterfowl. Traditional management procedures have been further modified by practicing a partial drawdown, as opposed to a complete dewatering, in early spring and maintaining a partial drawdown condition until early to mid-summer. During this period, trunk gates and spillways are adjusted to continuously circulate water, maintaining the marshes in very shallowly-flooded and/or saturated soil condition. Following the partial drawdown phase, individual management units may be drawn down completely for a brief period to stabilize soils for optimum widgeongrass production once the marsh is reflooded. Upon reflooding, water levels are gradually raised and vigorous water circulation is maintained through summer and early to mid-fall. During the period of late fall and winter, water levels are gradually lowered to enhance/maintain waterfowl food availability.

Modifications of traditional management schedules serve to improve habitat conditions for waterfowl and enhance potential for mosquito control and non-game wetland wildlife and estuarine fisheries management. Delaying reflooding for widgeongrass production results in maximum standing crops being available for use by migrating and wintering waterfowl. The maintenance of saturated soil conditions enhances the growth of other waterfowl food plants including saltmarsh bulrush and dwarf spikerush. Saturated to shallowly flooded conditions minimize production of salt marsh mosquitoes by maintaining high soil moisture content and preventing fissuring of marsh soils (Fleetwood et al., 1978; Vorgetts and Ezell, 1978). Saturated substrates also serve to maintain higher soil pH values which enhance plant vigor and growth but discourages egg laying by salt marsh mosquitoes. The abbreviated period of complete drawdown also minimizes mosquito breeding potential. The partial drawdown period coincides with annual spring shorebird migrations and therefore provides foraging habitats for numerous shorebird species as well as other water bird groups. Benthic invertebrates are made available for shorebird use on exposed and shallowly flooded mud flat areas (Wenner, 1986); whereas, wading birds and aerial and surface divers feed on fish in deeper water habitats associated primarily with interior and perimeter canals (Epstein and Joyner, 1986). Water circulation throughout most of the spring, summer, and early fall allows for water exchange over prolonged periods and therefore enhances recruitment and emigration of transient estuarine species. More continuous circulation further benefits fishery resources by maintaining higher concentrations of dissolved oxygen and minimizing water temperatures during potentially stressful summer periods.

Maintenance of the water quality through delayed flooding and extended periods of water circulation enhances management potential for not only waterfowl food production but also for certain important recreational and commercial fishery species. Delayed spring flooding allows for the recruitment and extensive culture of white shrimp (*Penaeus setiferus*) in conjunction with widgeongrass management. Blue crabs (*Callinectes sapidus*) also are recruited during reflooding and circulation processes, and high populations are commonly associated with well managed brackish waterfowl marshes.

Additional management innovations to enhance waterfowl habitat, particularly in saline marshes, involve production of sea purslane (*Sesuvium maritimum*). Sea purslane is a low growing moist soil annual that produces an abundance of very small seeds that are utilized extensively by green- and blue-winged teals and northern pintails (Swiderek, 1982). Optimum establishment and growth occur on soils of high organic content. Sea purslane is unique in that it is the only seed-producing waterfowl food plant that can be encouraged by drawdown in marshes of high soil salinity. The typical management schedule involves an early to mid-spring drawdown for germination and early fall flooding to make seeds available to waterfowl. After several seasons of drawdown for sea purslane management, it often is desirable to maintain the area in a flooded condition to control competing vegetation, primarily seaside saltgrass (Distichlis spicata), and to simultaneously promote the growth of widgeongrass. An additional option involves early spring (April) drawdown, for purslane growth, followed by late summer (August) or early fall (September) flooding for widgeongrass production. These techniques involving rotational and multi-species management have proven successful in maintaining productivity and diversity in often difficult-to-manage high salinity marshes.

Through coordinated management efforts it is possible to control species of competing vegetation and encourage waterfowl food production in the same marsh during a single growing season. For example, the cutting of common reed (Phragmites communis) at or near marsh level followed by flooding to depths of 18 to 24 inches for one growing season has proven to effectively control this highly desirable and competetive species. Flooding, for common reed control, is coordinated with the routine reflooding process in early to mid-summer and, therefore, is compatible with waterfowl food plant production. Once the area is flooded, limited cutting or removal of sprouted plants may be necessary to achieve complete control. This technique is most applicable in situations of limited common reed infestations where herbicidal application is judged to be undesirable.

Although traditional brackish and saline marsh management schedules have been modified to more effectively meet diverse interest in coastal wetland resources, certain limitations continue to exist. As managed wetlands are dynamic habitats that are characterized by annual variations in habitat conditions associated with weather factors, plant succession, and past management practices, wetland managers must maintain a certain degree of flexibility in their annual habitat management procedures so as to effectively achieve desired results. Quality management is dependent upon adequate numbers of properly designed trunks and a system of canals and embankments commensurate with the size and topography of individual management units. Finally, the successful achievement of multispecies management objectives requires timely water manipulations by alert, well-informed managers.

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## Multi-Species Utilization Of Waterfowl Impoundments

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As part of the S.C. Sea Grant Consortium Study conducted on the Tom Yawkey Wildlife Center's experimental managed marshes outlined earlier this afternoon by Doug Baughman, we conducted an investigation on water related bird utilization of managed marshes (rediked ricefields) and adjacent old ricefields that have not been rediked and have no water control structures. The study area is located near the junction of the Atlantic Intracoastal Waterway and the North Santee Bay. The salinity range at the time of the study was normally 0 ppt in the spring to 32 ppt during late summer and fall, averaging about 20 ppt during the growing season for widgeongrass, _Ruppia maritima_. The normal management strategy of the area had to be modified to permit other investigators to conduct their sampling procedures on individual units. For instance, during periods of drought and late season high salinities, fresh water sources at the upper end of the pond series could be released through the system of interconnecting spillways to freshen and/or improve water circulation. However, such techniques were not used during the CWIP.

Management objectives during the study were to promote production of waterfowl food plants such as widgeongrass, dwarf spikerush, _Eleocharis parvula_, and saltmarsh bulrush, _Scirpus robustus_, utilizing traditional brackish water management procedures and, secondarily, discouraging competitive emergents like _Spartina_ sp. and algae (e.g., _Cladophora_ sp.).

Draining of the remaining few inches of water from the managed marsh beds, after slowly decreasing levels beginning in October of the preceeding year, was accomplished in March. From late March until May the managed marsh beds were kept saturated with water levels in the perimeter ditches at bed level. In late April, in order to inhibit mosquito production, the beds were flushed by an addition of water over the bed in order to hatch any deposited eggs to larvae, followed 3 or 4 days later by draining or flushing of the larvae and quickly reflooding before eggs were again deposited on the marsh beds.

Gradual water addition and somewhat limited circulation were accomplished during the summer by keeping the outside trunk doors completely open and by adding boards to the spillway boxes. The very limited amount of rainfall was also retained by the addition of spillway boards. As water levels increased to approximately two feet on the bed, water exchange decreased and was limited to the top of the high tides.

Gradual water level reduction was begun in late October with the arrival of wintering waterfowl, although blue wing teal arrived as early as August, and continued throughout the winter as the available widgeongrass and seeds were utilized. During the 19-month field study in 1983 and 1984, a total of 1,544 observation periods were conducted from elevated blinds located on dikes between the managed impoundments and the old ricefield area that is now tidal, typical of Spartina marshes. There were 141,426 observations of individual bird use days, or 2,778 use days per acre, recorded for these species. Fifty-six species were observed using the unmanaged sites, while 76 species were observed using the managed marshes. Annual average use days totaled 222,043 on the approximately 150-acre area.

Briefly, a number of other findings from this research effort are as follows:

- Bird use was directly related to the decreasing water level, which was the most important variable.
- Spring water level was the most important variable.
- The largest number of birds were observed in spring, followed by winter, fall, and summer in that order.
- Shorebirds contributed 54.8% of the annual use with highest numbers in spring (Fig. 1).
- Waterfowl were second with 26.8% of the annual use and as expected predominate in the winter with 35,792 average winter use days (Fig. 1 and 2).
- Nine of 15 species of wading birds were predominate during summer with 7,787 use days and in fall with 9,933 use days (Fig. 2 and 3).
- Southern bald eagles averaged 81 annual use days and were more common from January through April while nesting in the area.
- Northern harrier (marsh hawks) occurred most frequently from September through April.
- Ospreys were recorded every month except January but predominately from March through September while nesting in the area.
- The most heavily utilized sites were the managed marshes

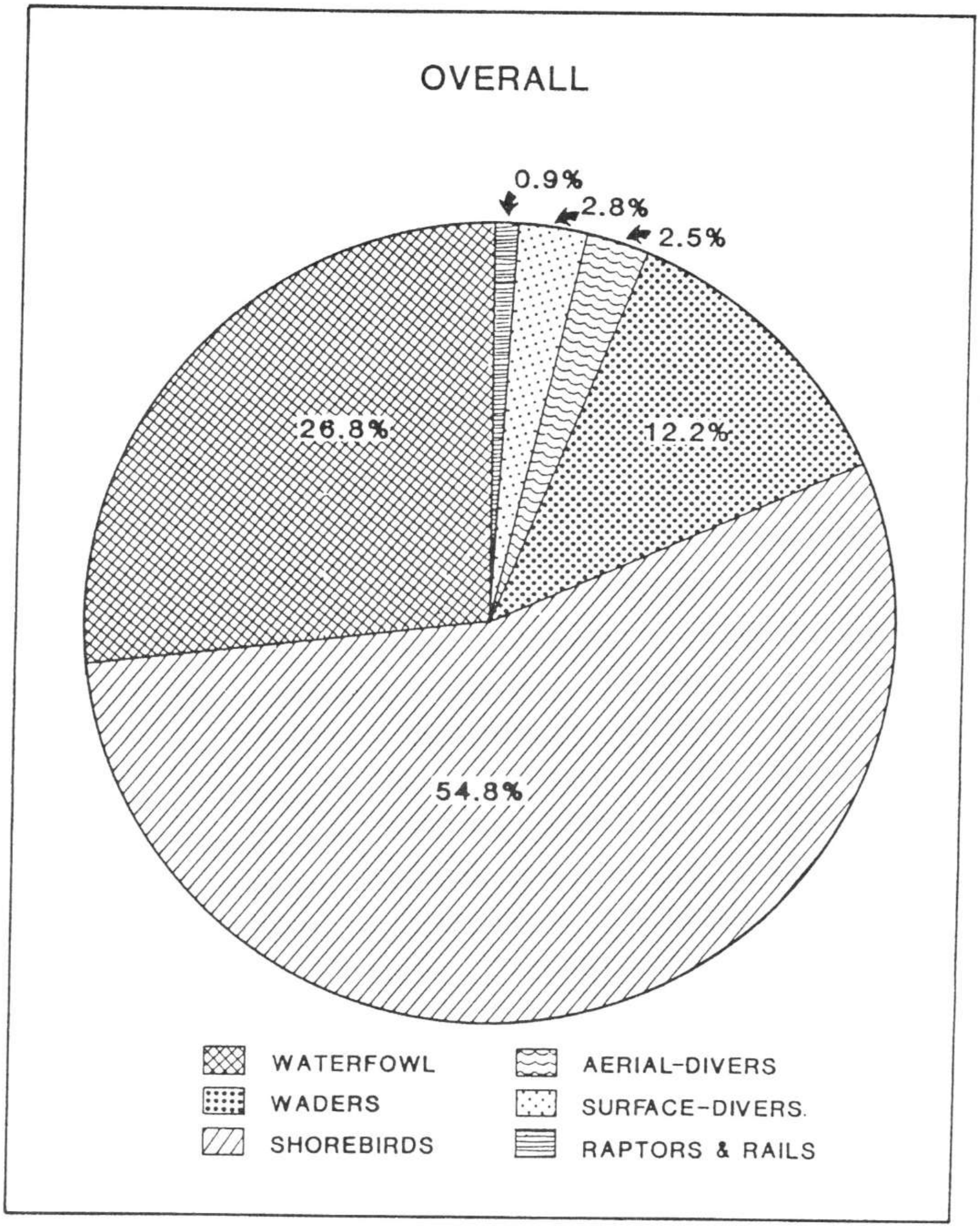


Figure 1. Relative average annual use-days for seven waterbird groups, 1983 to 1984.

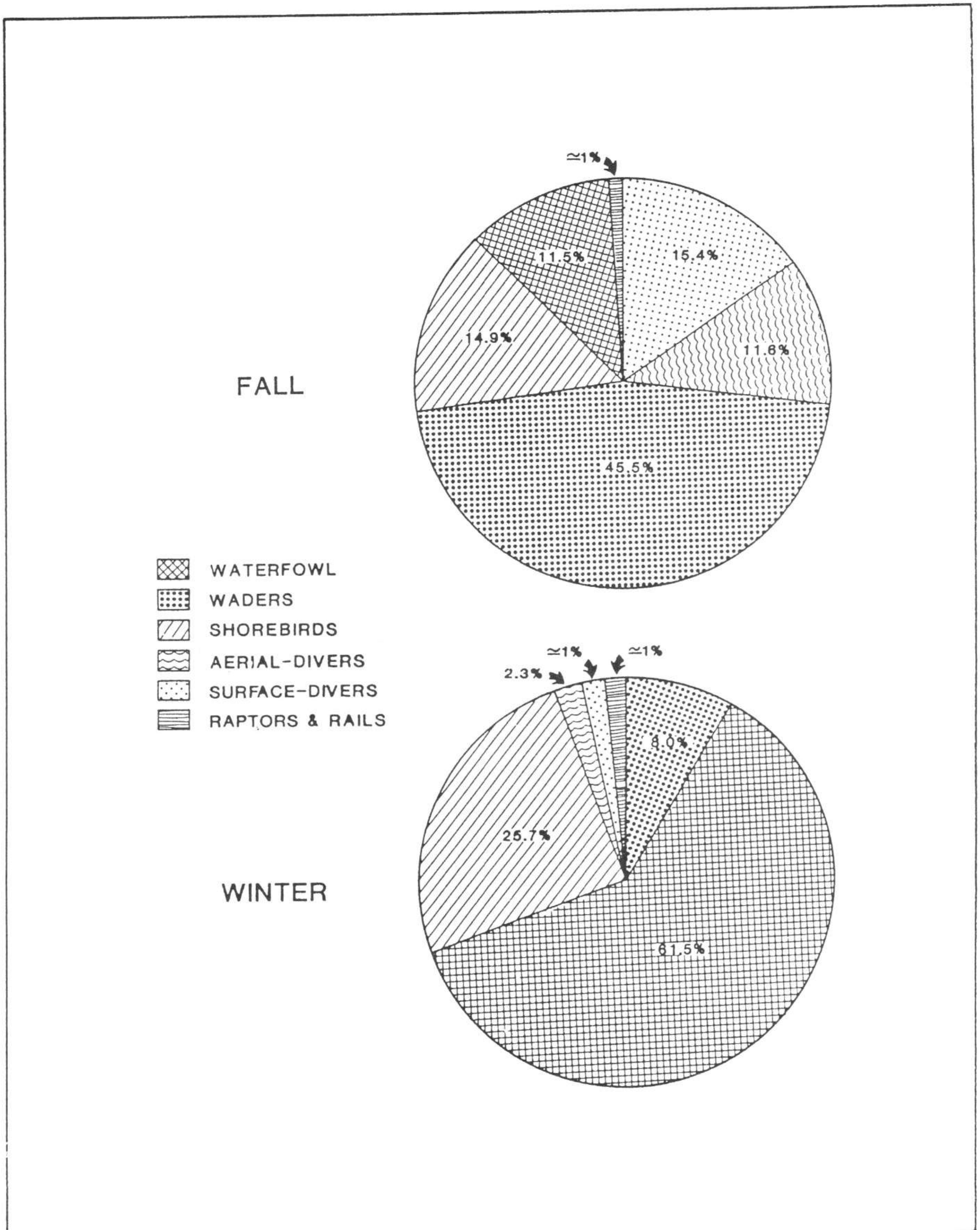


Figure 2. Average fall and winter utilization by seven waterbird groups, 1983 to 1984.

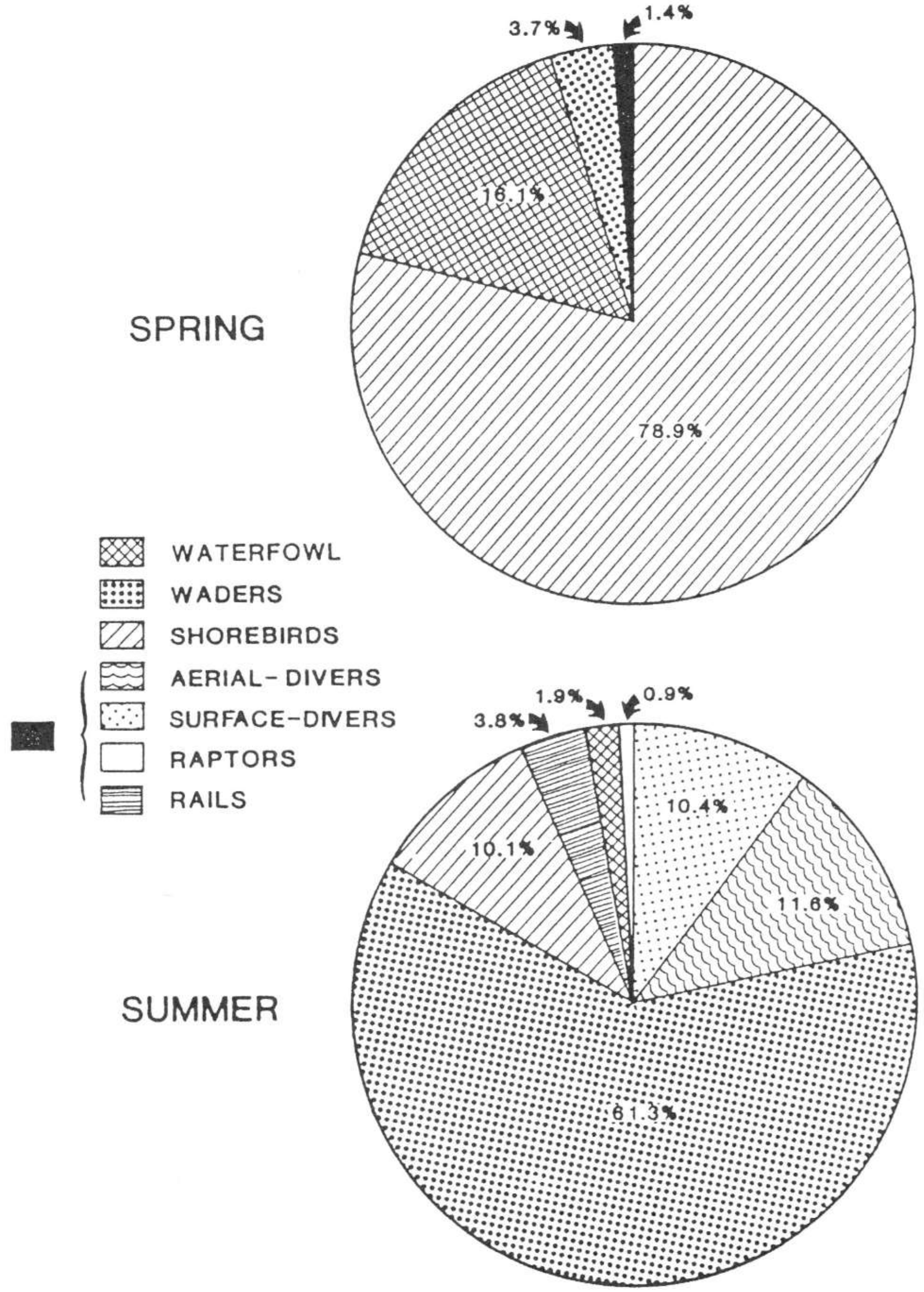


Figure 3. Average spring and summer utilization by seven waterbird groups, 1983 to 1984.

with the larger 33-acre impoundment, Cooperfield, as the most used while the least used was the tidal impoundment in all seasons by all species except clapper rails.

- There were 502 alligator observations made during the study, again predominately in the larger impoundment, Cooperfield.
- Previously, only 68 waterbird species were reported for South Carolina impoundments while 76 were recorded during this study.

High waterbird use of managed marshes appears directly related to season, management strategy, unit area, and resource availability. Managed marshes for waterfowl in brackish areas provide water level manipulations and resultant depths where food and prey are dramatically increased. This benefits a great variety of game, non-game, and endangered species. These results have major implications for multi-species management practices in South Carolina coastal wetlands. Slight alterations of water level strategies to increase water movement and increase resource availability can enhance conditions for many wild species and still maintain high waterfowl utilization.

## ADDITIONAL CONSIDERATIONS REGARDING MULTI-SPECIES UTILIZATION OF MANAGED MARSHES

During construction or topping of dikes, including wider banks or broader berms should be considered to promote growth of greater varieties of grass, shrubs, and eventually trees. There is the possiblity that these larger plants may be blown over and damage the bank or berm, requiring spot repairs. However, these plants act as wind breaks and may serve to curb erosion. They can also become an extension of the upland and increase the bountiful edge effect for a variety of birds, mammals and reptiles, not to mention enhancing the beauty of the area.

It may be desirable to think about establishment of grass turf on large perimeter banks to prevent erosion and provide grazing and seed production. Many times considerable mourning dove utilization, along with marsh rabbits, deer and coots, can be promoted. In this regard it may be necessary to spread a thin layer of topsoil or sand on these banks to promote this type turf. The point from which this topsoil is obtained, particularly in more saline areas, should be dug out to form a freshwater pothole. Particularly during periods of drought these potholes become very important and intensively used habitats.

If you are fortunate in having banks that connect small wooded islands and/or forested uplands, consideration should be given to leaving any large trees as potential nest sites. Studies have statistically shown that eagles are more likely to nest in the immediate vicinity of impoundments. The ospreys, as we all know, prefer the dead snags over or near water and these snags should be protected from fire. Many other species which nest here or migrate through the area utilize these snags; particularly the rot resistant cypress and cedar. Artificial poles and platforms can even be erected for nesting or perching. Thickets on these islands and uplands adjacent to impoundments are often utilized as roosting sites for mourning doves and, frequently, hundreds of wading birds.

Burning should be a tool used properly and with forethought and preparation to accomplish set objectives and not just as a matter of habit. When burning, care should be used to protect nest sites, roost sites, mast producing trees, etc.

As mentioned earlier, impoundment size can be essential to proper management potential for target species. Cross dikes within larger ponds can often be the answer to better water control and circulation. They also may be utilized to add variation in management procedures, stagger draining and flooding, offer different salinity situations, vary cover conditions, and generally afford a greater variety of plant and animal species. You don´t have all of your eggs in the same basket!

We may summerize some of the options and advantages connected with the increased number of manageable units as follows:

- Ability to provide greater variety of food sources.
- Separate areas can be provided for better cover and deeper water for severe winter conditions.
- Fresher water areas can be provided for those species that prefer them.
- Areas may not need to be drained each season to provide greater production.
- Areas can be dewatered at staggered rates.
- Areas can be burned and others left unburned.
- Area can be harvested for fish or shrimp and others left undisturbed.
- Species nesting in an area like shorebirds and alligators,

can be permitted to complete their nesting without being flooded out.

- Extended gradual draw downs can be offered for shorebirds.

And don´t forget that the smaller units make it easier to flush in the time frame needed to inhibit mosquito production when reflooding in the summer.

Perhaps with the Sea Grant Study and the information provided as a result of meetings like this one, we are on the way to dropping the term "impoundment" and adopting and implementing "managed marshes" or "managed wetlands."

## Combination Management for Aquaculture and Waterfowl

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Clemson/Sea Grant Marine Extension Program

### INTRODUCTION

Since the early 1900's, when the rice culture industry in South Carolina ended, the primary management goal in South Carolina wetland impoundments has been the attraction of waterfowl. Management regimes were designed to increase production of aquatic plant species through specific draining and flooding manipulations. In the late 1950's and early 1960's, Dr. Robert Lunz at the Bears Bluff Laboratory on Wadmalaw Island pioneered the management of coastal impoundments for the production of native penaeid shrimps. The management scheme also incorporated a specific draining and flooding schedule. As a result of this research, brackish and saltwater impoundments held the potential for aquaculture management. In the early 1980's, following the success of Louisiana rice farmers, South Carolina coastal impoundments were stocked with crawfish in an attempt to produce an alternative commercial crop. The specific flooding and draining cycles offered impoundment managers an opportunity to attempt combination management for aquaculture and waterfowl.

### WATERFOWL-PENAEID SHRIMP MANAGEMENT

In brackish and saline waters the primary management scheme is the draining and flooding of impoundments at specific times for the production of widgeongrass, _Ruppia maritima_, to attract waterfowl (Table 1).

Table 1

WIDGEONGRASS-WATERFOWL MANAGEMENT

| | |
|---|---|
| March- | Drain |
| March-May- | Moist |
| May-June- | Flood |
| June-October- | Circulate and Increase Levels |
| October-March- | Decrease Levels |

Dr. Robert Lunz at the Bears Bluff Laboratory on Wadmalaw Island, south of Charleston, S.C. developed a similar management scheme for penaeid shrimp in the late 1950's and early 1960's (Table 2).

Table 2

EXTENSIVE PENAEID SHRIMP MANAGEMENT

| | |
|---|---|
| MARCH-APRIL | As needed, repair trunks and dikes after obtaining permits. |
| MAY | Drain impoundments and rotenone remaining water. |
| JUNE | Screen and flood at night during maximum postlarval white shrimp concentrations. |
| JUNE-SEPT. | Allow for water circulation, using the tides, of 10% per day. |
| SEPT.-OCT. | Harvest by trawling or draining. |

The schedules for widgeongrass management and penaeid shrimp management align well as the timing of major water level changes are of extreme importance in combination management. If the water quality parameters and major water exchanges of the two management schemes are compared (Table 3) the potential for combination management can be easily realized.

Table 3

WATERFOWL-PENAEID SHRIMP MANAGEMENT

| | Widgeongrass | Shrimp |
|---|---|---|
| PH | 5.5-7.0 | 6.0-8.0 |
| Salinity | 8-15 ppt | 10-20 ppt |
| Flood | June | June |
| Stocking | Gradual | Gradual |
| Circulation | Yes | Yes |
| Draining | February-March | October |

The values for pH overlap but in practice pH levels tend to favor widgeongrass production which may reduce penaeid shrimp production slightly.

Salinity ranges are fairly similar; since widgeongrass and penaeid shrimp can withstand wide salinity ranges no major problems with salinity should occur, except at the highest and lowest natural levels.

Flooding schedules coincede nicely. June flooding dates for widgeongrass are a relatively new addition to the management scheme. The S.C. Sea Grant Consortium Coastal Wetland Impoundment Project determined that earlier flooding dates were producing maximum levels of widgeongrass before waterfowl migrated to the site. By waiting to flood in June, maximum widgeongrass levels coincide with the waterfowl season. Concurrently, penaeid shrimp will be occurring in the adjacent streams and can be recruited.

Water levels are closely regulated in both schemes and with increasing water levels and adequate circulation, widgeongrass and penaeid shrimp levels increase throughout the season.

Water circulation is extremely important in both schemes. In widgeongrass management, circulation reduces temperatures by bringing in fresher water, and water movement reduces noxious filamentous algae. Water exchanges of 10% per day or more are required in penaeid shrimp culture to maintain dissolved oxygen above the three parts per million (PPM) tolerance level.

Widgeongrass impoundments are drained in February or March after the waterfowl season ends in South Carolina. Harvesting of penaeid shrimp occurs in September and October. Shrimp are harvested by either trawling perimeter ditches or by draining. Trawling impoundments yields fewer shrimp per acre, but the impoundments do not have to be drained. Yields are in the 10-25 pounds per acre range, and widgeongrass production is not appreciably affected. If impoundments are drain-harvested, penaeid shrimp yields range from 50-100 pounds per acre depending on stocking success. If beds of widgeongrass are drained and exposed to the sun, decomposition will begin. In practice, penaeid shrimp tend to leave impoundments in mass and on night draining events when 1-4 inches of water remain on the bed. If impoundments can be immediately reflooded, widgeongrass should not be adversely affected (more research is needed to document the rates of decomposition and establish reflooding schedules for impoundments).

Screening of the intakes with 1/2-inch mesh hardware cloth is an effective means to reduce predator populations and increase shrimp yields (by up to 100%). The downside risk of screening is a reduction in water flow and the potential for loss of both widgeongrass and shrimp crops due to a lack of circulation. Unless managers are willing to check and clean screens regularly the downside risks outweigh the benefits of screening.

Combination management for waterfowl and shrimp can be successful and has been practiced by such innovative managers as Mr. Graham Reeves, Mr. R. Kenneth Williams, and Dr. Bob Lumpkin. Their success should encourage more managers to practice this multiple species management regime.

WATERFOWL-CRAWFISH MANAGEMENT

Following the successes of crawfish farmers in Louisiana and Texas in utilizing ricefields for crawfish production, South Carolina impoundment owners and managers have explored the potential of crawfish management. Initial attempts to stock South Carolina impoundments occurred in the late 1970's, but commercial production in ricefields actually started in 1981.

Freshwater impoundments in South Carolina had been managed since the early 1900's for natural vegetation to attract waterfowl. Later attempts have been made to plant forage crops, primarily grain crops, to increase waterfowl utilization. As Louisiana and Texas rice farmers utilized crawfish as a double cropped product with commercial rice production, South Carolina impoundment managers were seeking to double-crop waterfowl and crawfish.

Freshwater natural vegetation management for waterfowl (Table 4) and crawfish management (Table 5) have similar schedules of major flooding and draining events. Impoundments are drained in the summer months and flooded during fall and winter. The major difference in the schedules is the draining

Table 4

FRESHWATER WATERFOWL MANAGEMENT: NATURAL

| | |
|---|---|
| March-April- | Drain |
| May- | Flood to Bed Level |
| May-Sept.- | Saturate Bed |
| Sept.-Oct.- | Drain |
| Oct.-Nov.- | Burn |
| Nov.-Feb.- | Flood |

Table 5

CRAWFISH MANAGEMENT

| |
|---|
| May- Stock Prepared Pond |
| June- Drain Over Ten Days |
| June-July- Plant Forage Crop |
| Sept.-Oct.- Flood Pond |
| Nov.-May- Harvest Crawfish |
| June- Drain and Restart Cycle |

period. In spring, impoundment beds are drained and dried out to allow the seed of natural plants to germinate in waterfowl management, whereas draining occurs in early summer in managed crawfish impoundments. If crops are planted for waterfowl, however, the draining date should be delayed until early summer to coincide with the crawfish management scheme.

When the characteristics of freshwater waterfowl management and crawfish management are compared (Table 6), the potential for combination management becomes evident.

A wide variety of grain crops can be planted for waterfowl, while rice is the only recommended forage crop for crawfish. Recent advances at the Louisiana State University Agricultural Experiment Station on sorghum as a successful forage crop for crawfish has added a new potential crop for both waterfowl and crawfish production.

Table 6

WATERFOWL-CRAWFISH MANAGEMENT

| | Waterfowl Crops | Crawfish Crops |
|---|---|---|
| Crops | Millet, Corn, Rice | Rice |
| Natural | Wide Variety | Smartweed, Alligator-Weed, Water Primrose |
| Salinity | Fresh-Brackish | 5 ppt or less |
| Circulation | Important | Very Important |
| Harvest | Novemeber-January | November-May |

A wide variety of natural plants are suited for waterfowl while only three plant types are truly recommended forage for crawfish. Smartweeds are the only natural plants which offer good seed production for waterfowl and forage for crawfish.

Crawfish are freshwater animals and require salinities of 5 parts per thousand or less. Freshwater waterfowl management with either natural or planted vegetation requires the same salinity regime.

Circulation is important in maintaining access and proper vegetation management for freshwater waterfowl management. In crawfish management, circulation is of utmost importance. Circulating aerated water has been found to be the only method of maintaining dissolved oxygen above the 3 parts per million tolerance level in crawfish ponds.

The waterfowl hunting season and the crawfish harvest season initially appear to overlap in South Carolina, similar to the situation in Louisiana. In Louisiana, crawfish farmers compete with a wild harvest industry in the spring; their fall crop can bring twice the price of the spring crop. In South Carolina, crawfish farmers have no wild fishery competition, so a fall crop is not as important for production. Crawfish are cold-blooded animals, and trapping success is greatly reduced as water temperatures decline below $60^{\circ}F$. Louisiana's climate is approximately three weeks warmer than South Carolina's climate, therefore, the South Carolina crawfish harvest is smaller in the fall and winter than Louisiana's production.

Combination management for waterfowl and crawfish is in its infancy in South Carolina, and some compromise in management will need to be made. Successes have been made and further developments should increase the effectiveness of this type of management. The fees obtained for waterfowl hunting in South Carolina should outweigh any reductions in fall crawfish harvests.

## Management Innovations To Enhance The Use Of Impoundments By Estuarine Transient Species

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South Carolina Wildlife and Marine Resources Department

Sampling that was done for marine organisms right after an impoundment was flooded indicated that the organisms found on the inside of the impoundment and those in the tidal creeks were pretty much the same. The numbers of some species peaked higher in the impoundments during flooding because of the stockpiling effect. However, after the trunk doors were closed between the tidal water creek and the impoundment, the composition of organisms in the two systems changed. For example, the tidal creeks have different organisms in the water column at different times of the year. Therefore, the organisms that occur in the impoundment depend upon when the impoundment was flooded, and where in the estuarine system the impoundment is situated. Differences in the composition of organisms in the two systems, over time, become apparent as those species that do well in the impoundment environment grow and/or multiply, while others, not well-adapted, go through a decline or actually disappear.

Studies done on the Louisiana Gulf coast indicated that some bottom organisms don't cross over top water spillways. If an impoundment manager were to attempt to enhance the use of impoundments by estuarine transient species, then it appears from our present knowledge that two basic considerations must be met: 1) To keep water moving or flowing into and out of the impoundment as continuously and as often as possible while still meeting management objectives, and 2) allow inflow and outflow of water to occur at as many levels of the water column as possible. To accomplish these water manipulation strategies let us consider several possibilities, some of which have been tried and are in practice in a few areas now and others which have not been tried.

Table 1 shows some generalized waterfowl management strategies currently being practiced in various marsh types (based on salinity). In fresh and fresh/brackish marsh impoundments, water levels in the impoundments are maintained somewhere around the bed level during the growing season to create a moist soil condition. The management of this water level situation could be accomplished by setting an outside trunk door to an opening of about 3 inches. Water would flow into the impoundment on the incoming tide, and out again through an equal size inside door opening located in another location in the impoundment (Fig. 1). Under this management strategy, water would enter the impoundment when tide level is above the water-level in the impoundment and exit when tide level is below the impoundment water level (Fig. 2 & 3).

When the outside door and inside door are open about the same - in this case about 3 inches - then the area of inflow and outflow are at a ratio of 1:1. If these door opening settings are maintained the impoundment will begin to fill even though the area of the ´in´ and ´out´ openings are the same. This is because, at first, the average tide levels will be higher than the average water level in the impoundment longer than it will be lower. Therefore, there will be more time for water to flow into

| GENERALIZED WATERFOWL MANAGEMENT STRATEGIES | | | | |
|---|---|---|---|---|
| FRESH | FRESH/BRACKISH | BRACKISH | BRACKISH/ SALINE | SALINE |
| Summer drawdown to encourage naturally occurring seed producing annuals.<br>---<br>Flood during waterfowl season. Drawdown and keep water at about bed level during the growing season. | Summer drawdown to encourage naturally occurring seed producing annuals.<br>---<br>Flood during waterfowl season. Drawdown and keep water at about bed level during the growing season.<br>---<br>During dry growing seasons when estuarine salinities are elevated, flood to kill undesirable emergents with saline water. | Slowly raise water levels during the growing season to encourage both emergent and submerged aquatics.<br>---<br>Full flood with gradual decreasing waterlevels from early fall thru waterfowl season.<br>---<br>Late winter to early summer drawdown for 4 to 6 weeks. | Slowly raise water levels during the growing season to encourage both emergent and submerged aquatics.<br>---<br>Full flood from early fall thru waterfowl season.<br>---<br>Late winter to early summer drawdown for 4 to 6 weeks.<br>---<br>Flooding strategies somewhat influenced by seasonal rainfall patterns. | Slowly raise water levels during the growing season to encourage both emergent and submerged aquatics.<br>---<br>Full flood from early fall thru waterfowl season.<br>---<br>Late winter to early summer drawdown for 4 to 6 weeks.<br>---<br>Flooding strategies strongly influenced by seasonal rainfall patterns.<br>---<br>Alternate between above management and growing season drawdown to encourage Sesuvium m. |

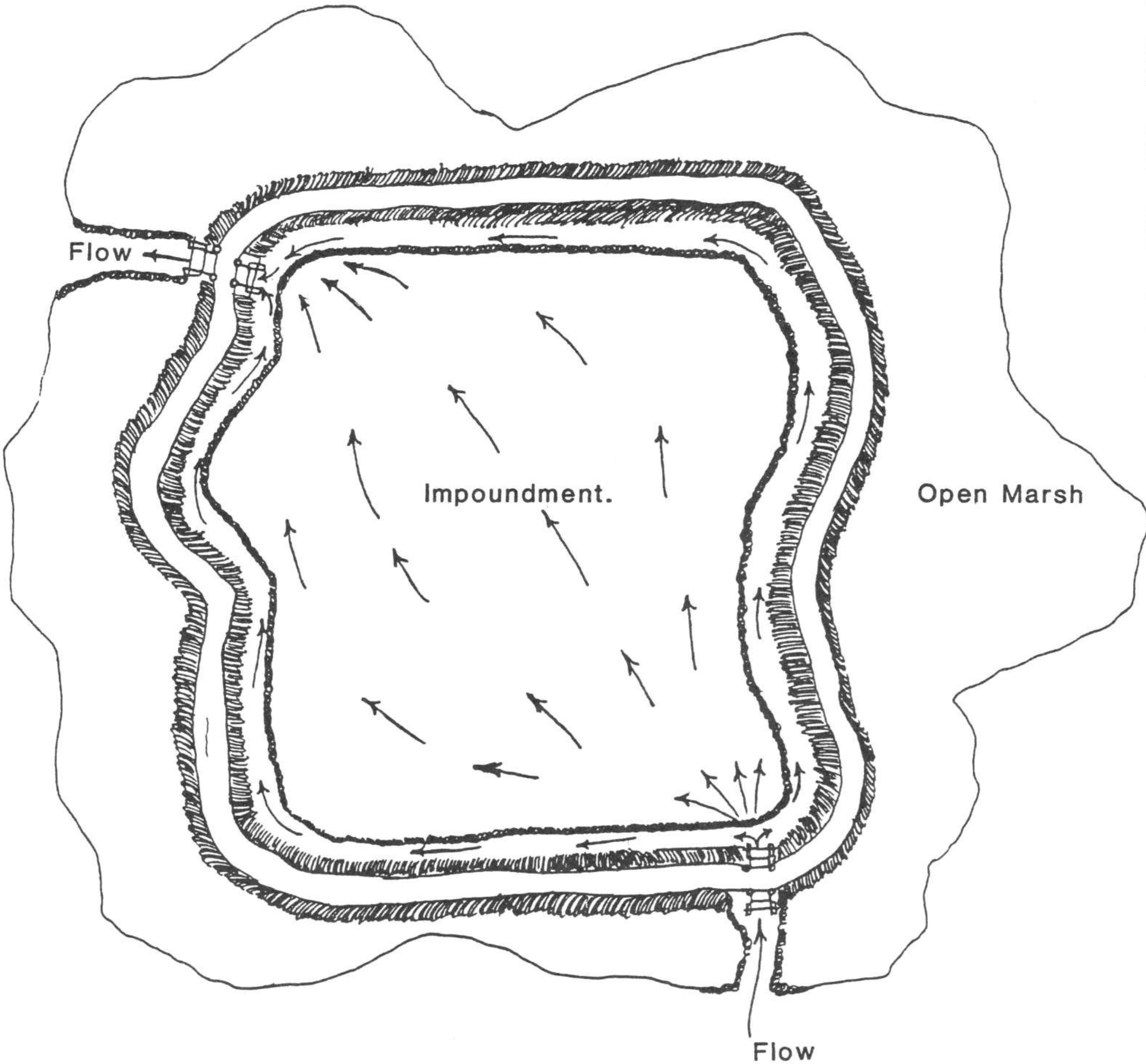
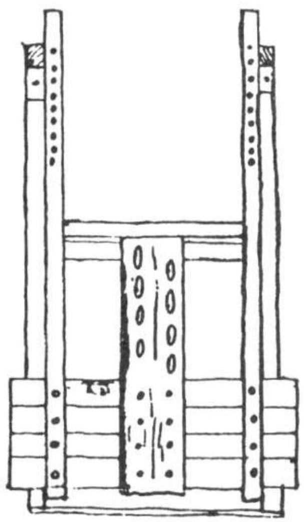
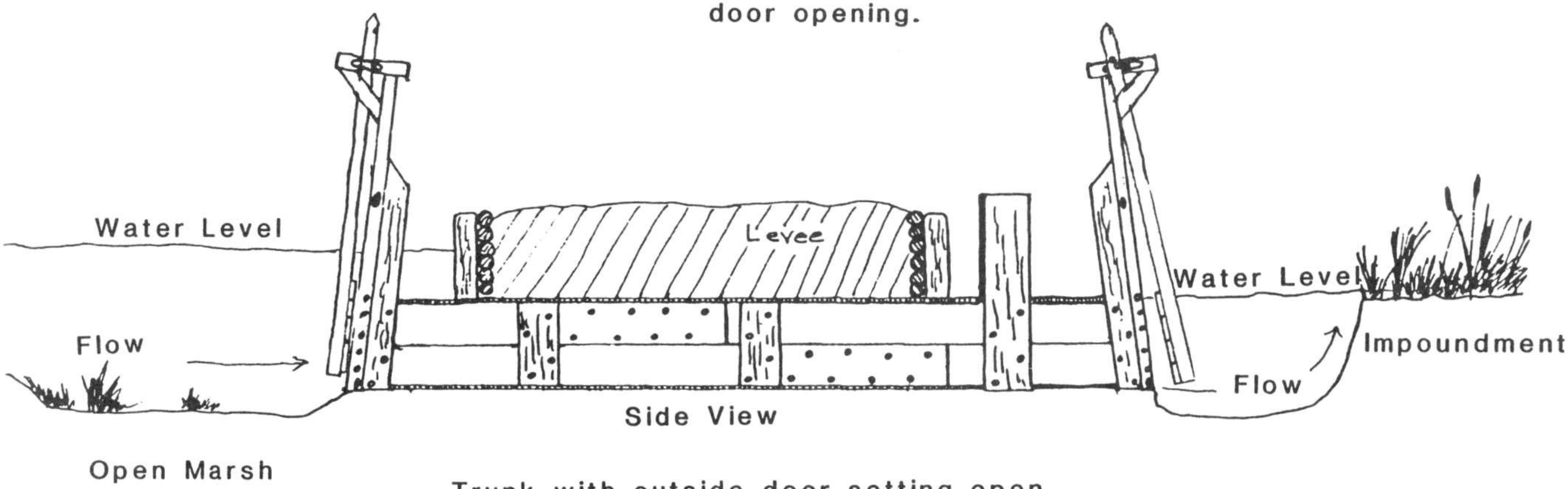



Figure 1

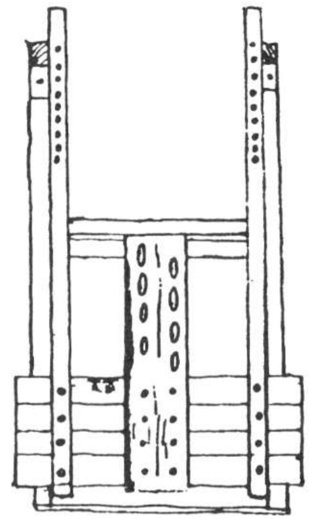


Front view of <u>outside</u> door opening.

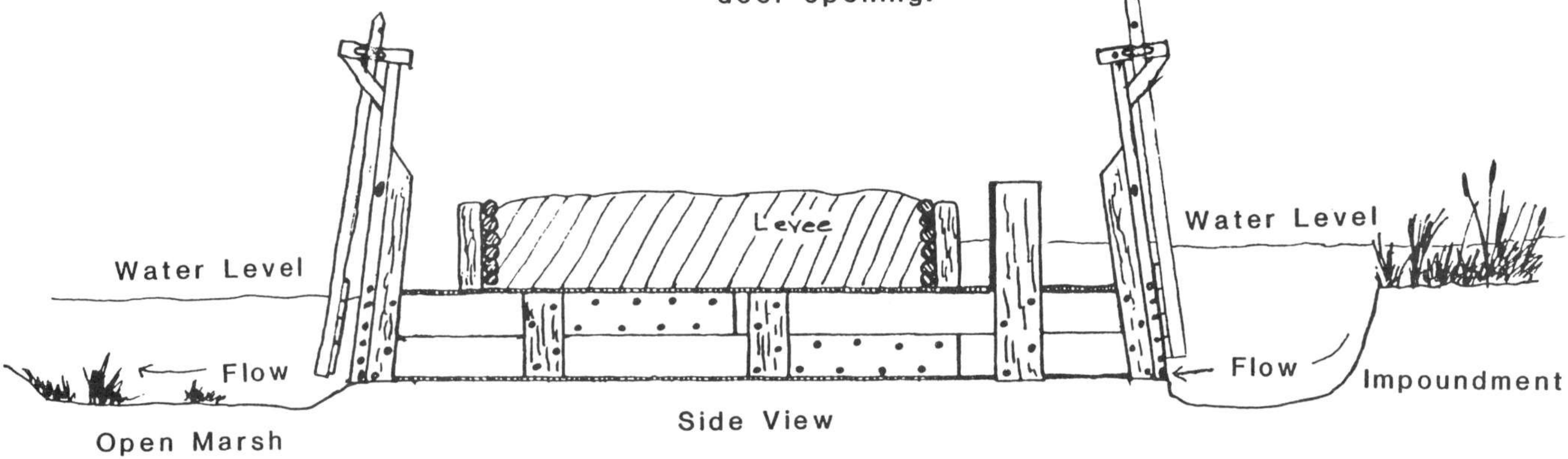



Trunk with <u>outside</u> door setting open 3" to flood the impoundment.

Figure 2



Front View of inside door opening.



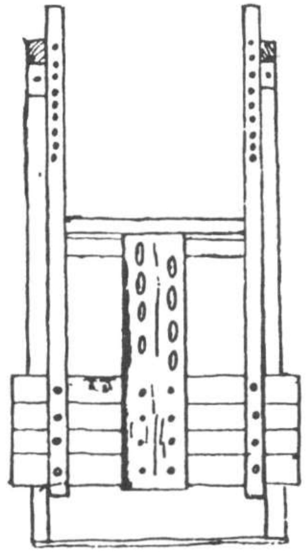

Side View

Trunk with inside door setting open 3" to drain the impoundment.

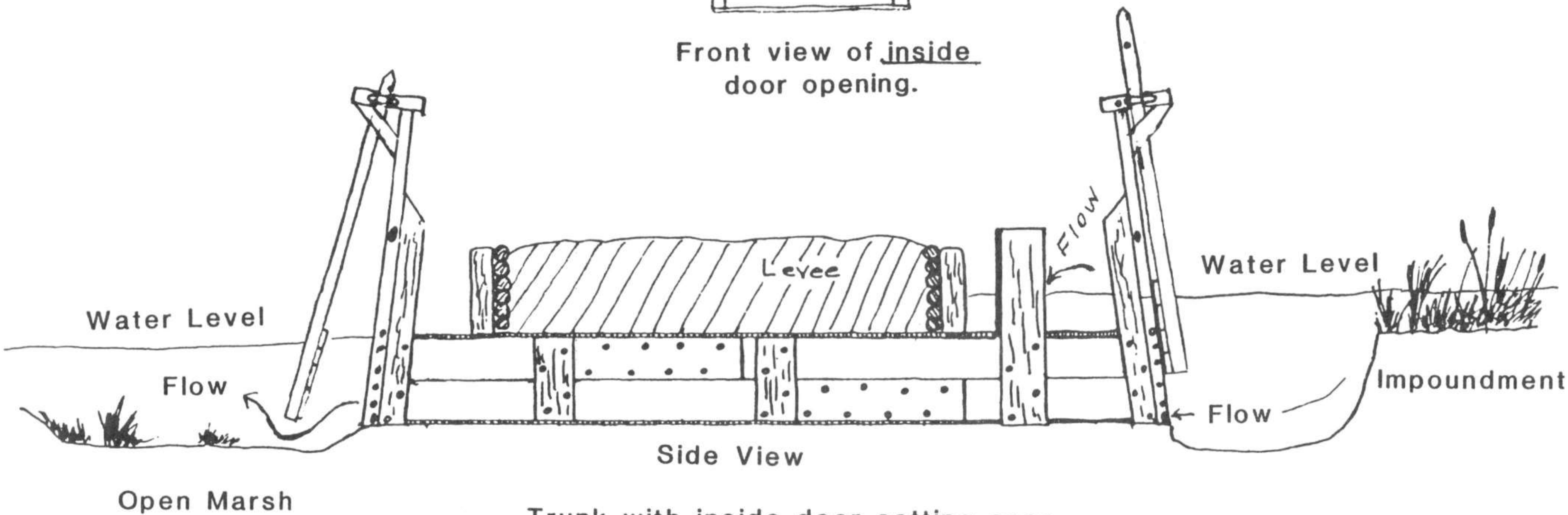
Figure 3

the impoundment than to flow out. Also as tidal water level begins to exceed impoundment water level, head pressure is created. As one water level increases in height over the other, head pressure increases and flow rate increases accordingly. While water level is low in the impoundment, flow-in time will greatly exceed flow-out time, and average tidal head pressure or the average flow-in rate will exceed average impoundment head pressure and the average flow-out rate. As the water level of the impoundment rises the difference between flow-in time and flow-out time, as well as the average difference in head pressure, will diminish. Equilibrium of flow-in/flow-out time and rate should be reached with equal size inflow and outflow door openings when the impoundment water level reaches the mid-tide range. When this state of water level equilibrium is reached certain adjustments in the size of the door openings may have to be made if a change in impoundment water level is desired. For example, if the impoundment water level exceeds the level necessary to maintain a moist soil condition at equilibrium, then the inside door opening could be increased to increase outflow-rate. Another alternative would be to set the top water spillway boards to allow excess water to flow over the top board of the spillway. This would allow water to exit the impoundment at the top and bottom of the water column simultaneously (Fig. 4).

If the desired impoundment water level is not reached at equilibrium, then the outside inflow door opening could be increased, possibly in combination with a slight lowering of the



Front view of <u>inside</u> door opening.




Trunk with <u>inside</u> door setting open
↑12" to drain the impoundment.

Figure 4

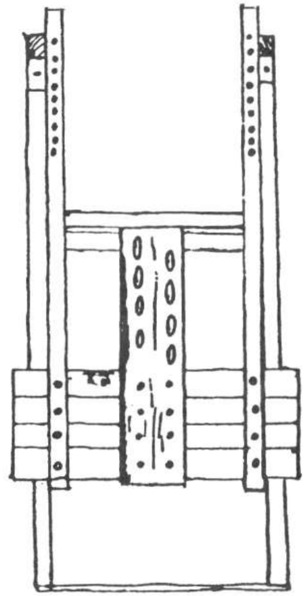
inside opening to raise the mean height of the water level in the impoundment.

After the growing season is completed, waterfowl management strategies call for impoundment water levels to be increased to depths of 6 to 12 inches on the bed for the waterfowl hunting season (Table 1). This has been done in the past by opening the outside door to flood the impoundment and then maintaining the desired water level by letting water in and out as needed. On large areas, this may be labor intensive. The possibilities also exist to have an almost fully-flooded impoundment by setting the outside door all the way open (Fig. 5), and closing the inside outflow door to 3 inches (Fig. 3).

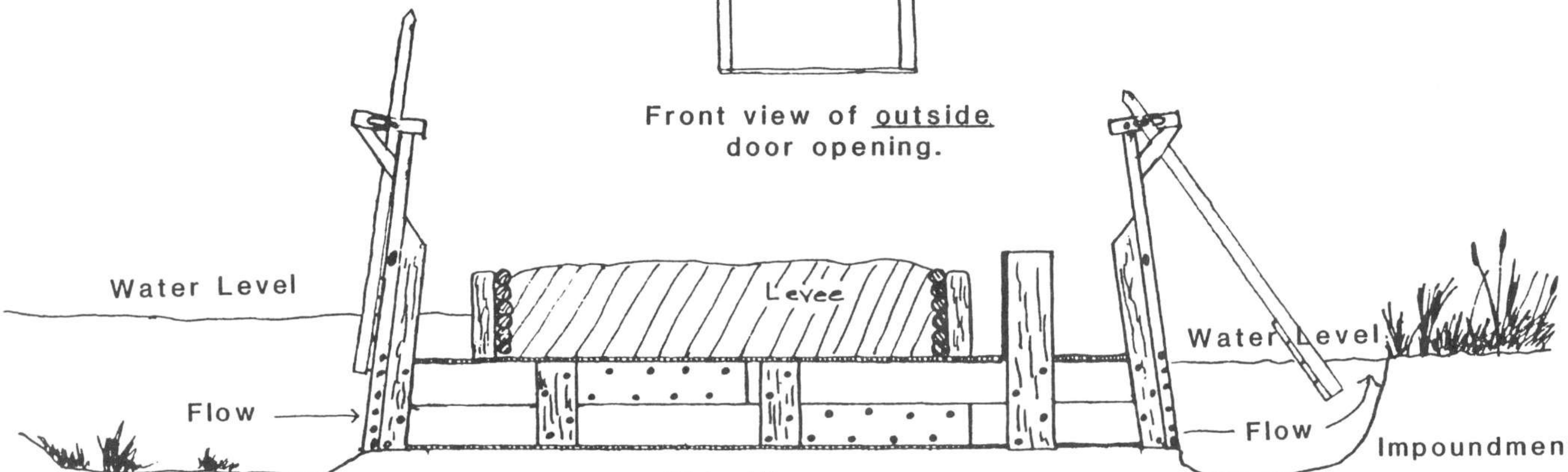
On a 2′x 5′ trunk door opening this would allow for an area ratio of inflow to outflow of 8:1. If an impoundment water level of 6 to 12 inches on the bed is somewhat less than mean high tide, which is usually the case, then equilibrium of inflow to outflow could be reached while accomplishing a continued water exchange between the tidal and impoundment systems.

Waterfowl management in brackish marsh impoundments usually is done by means of slowly rising water levels during the growing season. Flooding may be started anytime from late winter to early summer (Table 1). Slowly rising water levels can be attained by using a combination of inside and outside trunk door opening sizes, which causes different flow-in and flow-out rates.

One strategy of managing a slowly rising water level situation could be to open an outside, inflow door and an inside, outflow door to 3-inch openings, thus creating an area of inflow



Front view of <u>outside</u> door opening.




Side View

Trunk with <u>outside</u> door setting fully open to flood the impoundment.

Figure 5

to outflow ratio of 1:1. In the initial flooding stage, the water level of the impoundment will be below mid-tide range. Therefore, the mean water level of the tide will be higher than in the impoundment. This will cause an increased inflow time and rate into the impoundment over flow-out time and rate. Impoundment water levels, therefore, will increase at a steadily decreasing rate as the impoundment fills. The rate the impoundment floods to a pre-set level depends, of course, upon the area of the trunk door openings and the area to be flooded.

As equilibrium is reached between inflow and outflow, the impoundment water level will tend to stabilize. To continue the steadily raising water level management strategy, the outside door opening could be increased to 12 inches while leaving the inside door opening at 3 inches. The size of the inflow opening will then be 4 times greater than the size of the outflow opening.

As equilibrium is again reached, this time at a higher level in the impoundment, open the outside door to its fullest while still leaving the inside opening at 3 inches. The intake opening will now be 8 times greater than the outflow opening. As the water level in the impoundment exceeds the midpoint of the mean tide range then outflow time and rate begin to exceed that of inflow. Therefore large inflow openings must be maintained with decreasing outflow openings, if water levels in the impoundment are to continue to increase.

When equilibrium is again reached, this time at levels where outflow time and rate substantially exceed inflow, a piece of plywood could be placed in the spillway to close off the spillway and trunk opening. The inside door could be fully opened, and with a 10-inch diameter circular hole, cut near the bottom of the plywood, the area of inflow is now increased 18 times that of the outflow (Fig. 6).

As the impoundment water level approaches full stage, the 10-inch circular opening could be replaced with an 8-inch circular opening. This increases the ratio of the area of inflow opening to about 29 times greater than the area of outflow opening. This 8-inch circular opening, while substantially restricting outflow, still has sufficient height to allow passage of larger estuarine organisms. For a brief period during full flood stage, the outflowing impoundment water may have to pass over the top of the spillway to maintain the impoundment at its highest water levels. However, water exchange would continue between the two systems.

In brackish marsh impoundments, water levels are slowly lowered during late fall and winter when waterfowl is the primary objective of management. To slowly lower water levels during this period, the above process is reversed. First the outside door is left fully opened while the outflow opening is again reduced to an 8-inch circle.

As equilibrium is reached at a lower water level the opening is increased to a 10-inch circular hole and then to a 3-inch door opening. This of course gradually increases the opening area of outflow. As lower water levels continue to be reached, the inside door is gradually opened wider, and the outside door is

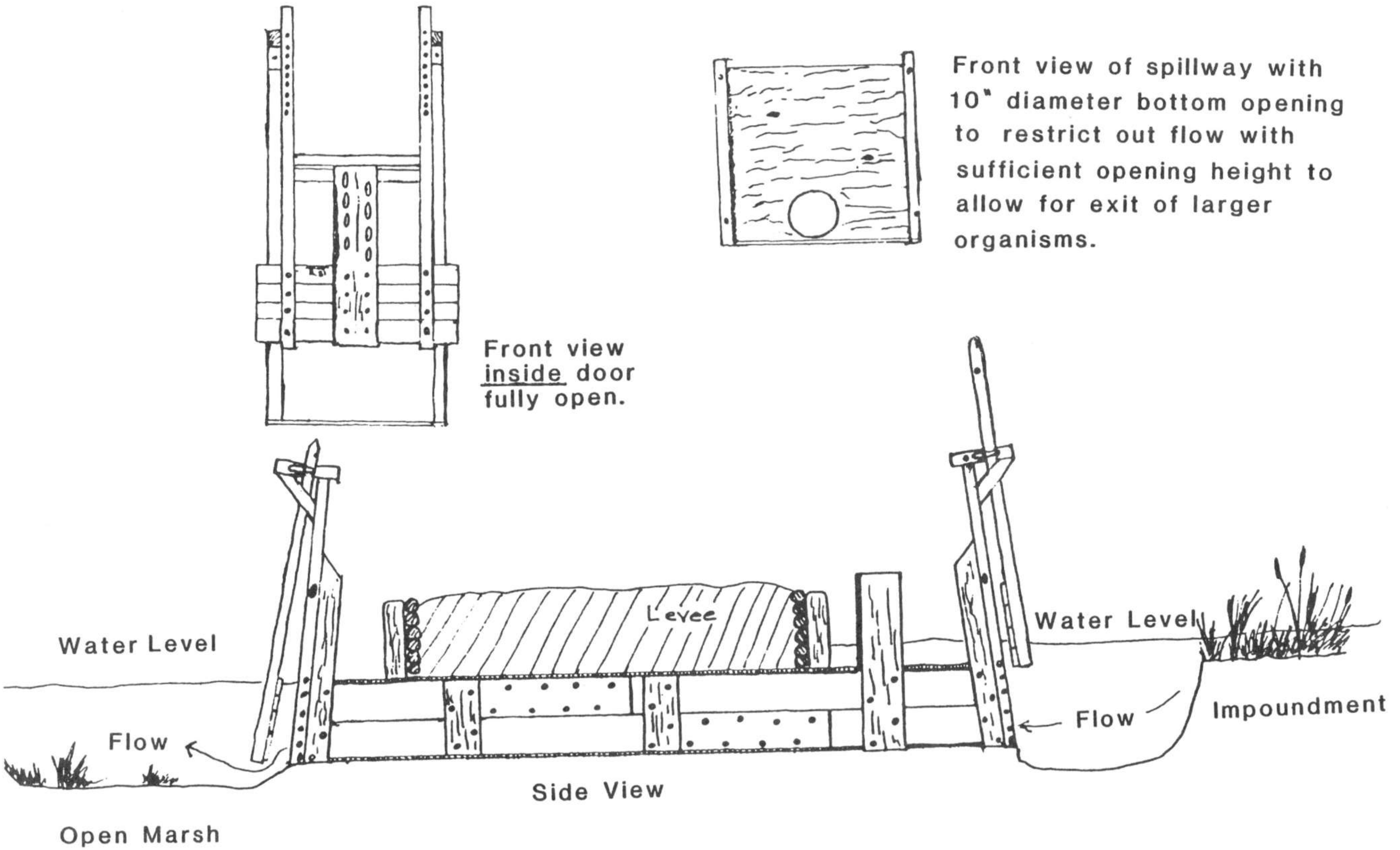

Front view inside door fully open.
Front view of spillway with 10" diameter bottom opening to restrict out flow with sufficient opening height to allow for exit of larger organisms.
Levee
Water Level
Water Level
Flow
Flow
Impoundment
Side View
Open Marsh

Figure 6

gradually closed, which will result in continuously decreasing water levels in the impoundment. Near the final stage of draw-down the inside door and spillway should be fully opened while the outside door is nearly closed (Fig. 7). This would allow some circulation before complete drawdown.

This flow-through management scheme would significantly increase the opportunity for organisms to move in and out of flooded impoundments, and make nursery areas available to a wide variety of organisms for longer periods of time. It would also improve water quality by lowering water temperature during hot weather, lessen problems with oxygen depletion, and allow the impoundment to function like the tidal marsh does for transient marine species.

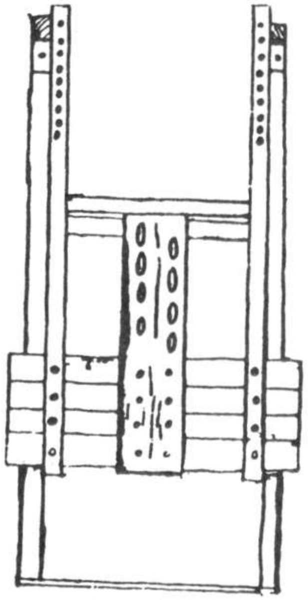
If done in a carefully tended manner, it would also produce quality conditions for waterfowl.

## CONCLUSION

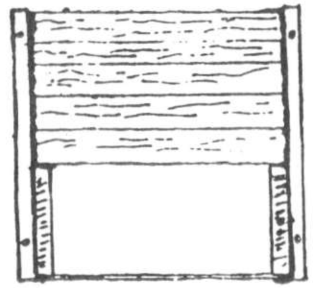
Combination management for aquaculture and waterfowl can be successful and offers impoundment managers a multiple-species management alternative.

Each management situation, however, has unique goals and objectives due to site location and the expertise, time and financial situation of managers and owners.

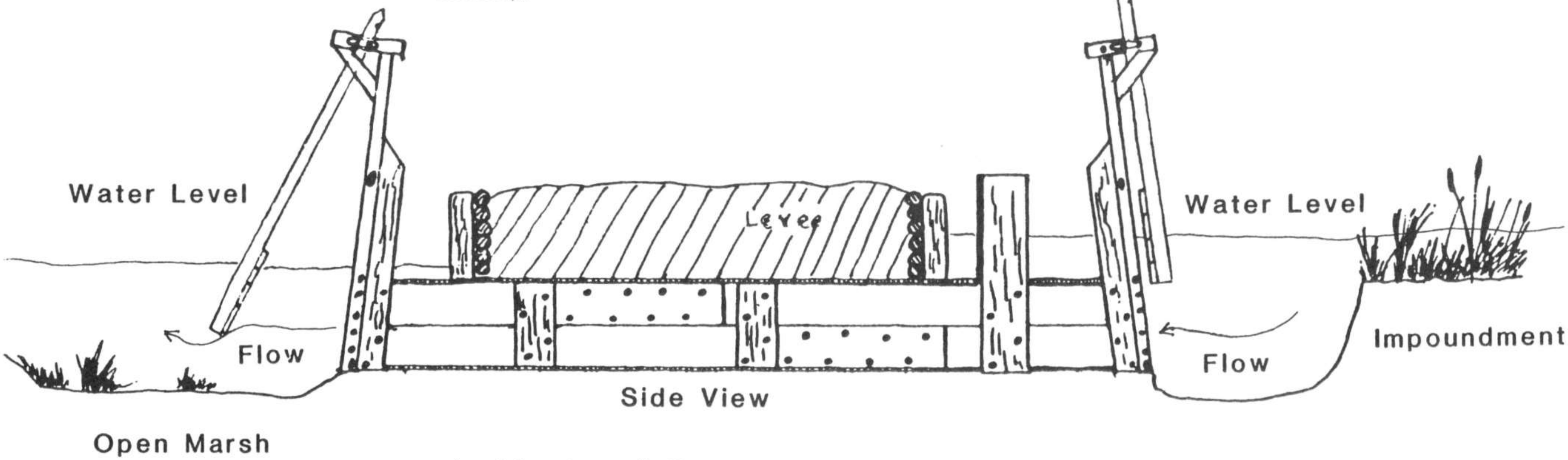
Management will take more time and financial effort if an impoundment is to be properly managed for aquaculture. Specific management goals, however, on single target species will usually exceed the goals of combination management for single target



Front view of
inside door
fully open.



Front view of spillway fully
open at the bottom to allow
full flow from the impoundment
to the outside.




Side View

Inside door fully open and spillway
fully open at the bottom to allow
maximum impoundment drainage.

products. Combination management for aquaculture and waterfowl has both benefits and conflicts with specific target management, but combination management can increase total production of all target species.